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THESIS

CREATING A SYSTEMS ENGINEERING DISTANCE LEARNING EXPERIENCE

by

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December 2014

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13. ABSTRACT (maximum 200 words)

This thesis investigated alternative online distance learning exercises that can emulate the learning experiences achieved through the conventional physical hands-on systems engineering laboratory or related team project efforts. The proposed approach uses a modified case study methodology to facilitate a structured discussion of system engineering principles. Instead of a detailed narrative to extract learning points in a traditional case study, these exercises are designed to enable the students to fill in the system engineering learning points in a cultural reference. A series of exercises templates has been created and using the “M*A*S*H”© television program as the cultural reference, and an initial series of exercises have been created to demonstrate the concept. These exercises were created to provide a single reference for multiple exercises during the introduction to system engineering classes. By using the same reference throughout the first class, the students will leverage prior familiarity with the topic to reinforce system engineering learning points. By revisiting the same example in classes later in the program, continuity across the program’s class will be highlighted, and the systems engineering learning principles will be demonstrated in a common cultural reference, in this case a historically referenced fictional environment.

The two primary objectives of this thesis were to 1) create and document the process for creating future system engineering case studies using a popular cultural reference, and 2) create an initial set of case study exercises that reinforces the systems engineering learning points. A series of 13 case study exercises have been created to meet these objectives.

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CREATING A SYSTEMS ENGINEERING DISTANCE LEARNING EXPERIENCE

Jeffrey Sachs

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ABSTRACT

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LIST OF ACRONYMS AND ABBREVIATIONS

AoA	analysis of alternatives
BIT	built in test
CAIV	cost as independent variable
CDD	Capability Development Document
CONOPS	concept of operations
COTS	commercial of the shelf
DAU	Defense Acquisition University
DOD	Department of Defense
EVM	earned value management
HSI	human system integration
JCIDS	Joint Capabilities Integration and Development Systems
KPP	key performance parameters
KSA	key system attributes
MASH	Mobile Army Surgical Hospital (references a military unit and as a system of systems)
M*A*S*H ©	the television series (references either the show or the exercises/simulation)
MOVES	Modeling, Virtual Environments and Simulation Institute
MSA	material solution analysis
NCAT	National Center for Academic Transformation
NPS	Naval Postgraduate School
PDF	Adobe© Portable Document Format
RBD	reliability block diagram
SE	systems engineering
SWOT	strength, weakness, opportunity and threat
UCLA	University of California, Los Angeles

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EXECUTIVE SUMMARY

"Tell me and I forget, teach me and I may remember, involve me and I learn."

Benjamin Franklin

The objective of the this thesis is to bring the systems engineering learning experiences out of the lecture-based classroom into practical exercises the students can relate to. Hands on experimentation permits students to learn for themselves in a safe friendly atmosphere, answering the questions of who, what, why and how a system works. Traditional case studies present a detailed narrative that provides the learning points within a selected context (Australian School of Business, 2012). The objective of this thesis is to create a process to generate system engineering case studies using a cultural reference as the context and have the students identify the learning points within the fictional context to simulate the hands-on experience. The initial set of exercises was created using the process and M*A*S*H© television program as the cultural reference. By requiring each student to participate in the web-based discussions that include the extraction and projection of systems engineering (SE) learning points onto the Mobile Army Surgical Hospital (MASH) unit and the M*A*S*H© television program should reinforce the systems engineering learning points to support the scholarly and professional activities of the students and faculty.

A secondary objective of this thesis is to create continuity within the Systems Engineering Program by showing how a common element (the M*A*S*H exercises and the MASH as a system) is applicable to elements of systems engineering. While the exercises are currently aligned with the introduction to system engineering classes, additional exercises that delve into specific knowledge areas can be easily integrated into other system engineer program core classes. By having case study exercises that tie each subsequent course into the same M*A*S*H system, the exercises will demonstrate the continuum of the Systems Engineering Program as a single process to a common cultural reference.

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Thank you to John Eghtessad, Bruce Herniter, CDR Todd Greene and others who discussed the concepts in depth and helped refine the final product. It is remarkable how little side comments can open entire new perspectives on a well-developed concept. One of those little comments truly enhanced my understanding of this paper, this effort and made the end result much greater than before it.

Thank you to Andy Guarino and the interns who participated in the M*A*S*H game simulation exercise trial run.

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The author would like to honor the memory of those NAVSEA co-workers who lost their lives on September 16, 2013 in building 197.

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I. PROBLEM STATEMENT

This thesis set out to identify some alternative methods for teaching or reinforcing the system engineering learning objectives. After investigating several mechanisms which are discussed in the Background Research on Digital Learning section, a technique using a common cultural reference and a modified case study methodology has been developed. Within the cultural reference (a movie or television program), the underlying system and system elements are never fully explained background items. Instead of trying to extract the learning points from a detailed narrative of the traditional case study, we are having the students fill in the system elements that were not fully explained in the cultural reference. This process is similar to what the system engineer will face where the objective and some constraints may be known initially, but there are many unspecified critical details and unknowns when designing a new system.

The two primary objectives of this thesis were to 1) create and document the process for creating future system engineering case studies based on popular cultural references, and 2) create an initial set of case study exercises that reinforces the systems engineering learning points.

This thesis is intended to get the students to use a case study like exercises to identify and explain the process, techniques, and approaches learned in class to specific examples, and get feedback in a discussion forum from fellow students. The students will use the concepts taught in class (understanding), to articulate an approach to specific examples (practice), and their classmate's feedback will provide the cyclical experience (recursive thinking). By working through these exercises as part of a class, the students should experience a learning environment that reinforces the systems engineering learning objectives. The discussion boards will permit the students to experiment with system engineering approaches and learning points answering the questions of who, what, why and how in a safe and supportive atmosphere.

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II. BACKGROUND RESEARCH ON DIGITAL LEARNING

In classical graduate programs, the students may have team projects, customer focused projects or laboratory classes that reinforce learning objectives. The background research effort focused initially on what other on-line system engineering programs were doing to reinforce the learning objectives outside of a traditional lecture class environment. The following research investigated what is currently happening in online learning that could be adapted to reinforce system engineering points. Two alternative approaches (computer based gaming, and a hands-on experience (Lego© Mindstorm© kit) were investigated further before settling on the modified case study approached.

A. DISTANCE SYSTEMS ENGINEERING PROGRAMS SEARCH

The initial guidance for this thesis from Naval Postgraduate School (NPS) was to investigate what other distance learning systems engineering programs were doing to meet the laboratory experience requirement. A website survey of 23 programs conducted in March of 2013, mostly at the master's level but extending to both bachelor and doctorate level programs, showed a lack of any virtual laboratory programs or software that could be adapted for NPS use. Two programs did have "laboratory" courses as part of their curriculum. Stevens Institute of Technology (Stevens Institute) had a virtual computer network, where blue and red teams either tried to protect the network or break into the network. The Stevens Institute secure systems laboratory course was more targeted to computer systems and network design and management versus the system of systems architecture than NPS programs focus on. The only other laboratory-like course was at University of California, Los Angeles (UCLA), which was a modeling course, on how to build computerized models. Several of the NPS Systems Engineering Program classes include Excel and risk simulation models that were broken out as a separate course at UCLA with some modeling theory included. One of the proposed M*A*S*H exercises involves an MSExcel© model, touching similar content as this UCLA course. Based on the course's syllabus, the UCLA class would fit better in the NPS Modeling, Virtual Environments, and Simulation (MOVES) Institute curriculum versus the SE

program. As a result of the lack of a virtual laboratory that could be adapted to the NPS needs, this investigation focused on how to leverage the existing software and tools to replicate the learning objectives for the distance learning environment.

B. REDUCING COSTS FOR EDUCATIONAL INSTITUTIONS

Previous online distance learning research has shown that online learning can achieve improved academic performance, evidenced by higher test scores, at a reduced cost to the educational institution and be expanded to larger audiences (Means, 2010). When properly implemented, learning of the various types, has demonstrated that it can achieve better performance as assessed by test performance, student and faculty satisfaction, increased retention rates, and reduced costs when compared to face to face learning of traditional programs (Abel, 2005). The Naval Postgraduate School (NPS) has embraced distance digital learning initiatives as evidenced by the creation of the PD-21 program in 2000.

The predominant area of previous research in online learning has focused on improving the basic understanding of core principles by students in the least expensive manner for the educational institution. The National Center for Academic Transformation (NCAT), funded largely by the Pew Charitable Trust and the Bill & Melinda Gates Foundation, has focused on bringing technology into the large lecture hall classes to improve student performance at a reduced cost. Where students historically have attended a large lecture hall class, with graduate student assistant breakout sessions, the NCAT has funded the creation of online tools to engage the students (active participation versus passive learning in a lecture hall) and to provide immediate and focused feedback on weaknesses of each particular student. This effort, dating back to 1999, has funded grants to various universities and community colleges to experiment with different techniques and technology. The major takeaway (Means, 2010) is that colleges have seen improved test scores and reduced costs after implementing the initiatives. The problem most often encountered with digital or distance learning is the cultural change that the faculty, institutions, and students were being asked to overcome (Kim and Curtis, 2006). An example of the cultural challenges is that some faculty who have matriculated through a

traditional educational system were loath to embrace the new technology, and personality traits of both the students and faculty made the most impact. Some faculty who were great lecturers, were unable to connect in the more individual assistance settings they were being asked to embrace. Inversely, some faculty who might struggle in the large lecture hall thrived in the individual online support roles. Student expectations both of what they expected from the university and online learning had equal impact on the individual student's achievement (Abel, 2005). Everybody is unique and learns or teaches in a unique way, which may or may not be conducive to the online environment (Felder, 1988). No one system is going to work for all students, and the proposed online laboratory experience may connect with some students but not others.

These NCAT funded efforts have focused on transitioning basic level courses from classroom and lecture environments to a self-directed process, where the students watch videos of lectures and examples, and then reiterate the information back through automatically scored quizzes. Once the student's answers are evaluated, the automated digital classroom walks students through additional lectures or exercises addressing just the answers the students got wrong, until the students pass the quizzes with 100 percent comprehension. These classes have included help sessions or resource centers (both physical locations and online chat rooms) where students can get additional human assistance.

The NCAT efforts and other research (Prince, 2004) show that automated models of online and distance learning have worked well in conveying basic material where there are discrete right and wrong answers, be it chemical formulas, math problems, proper grammar for English and other languages. What is lacking is the ability to convey the higher level analytical or practical implementation experience that is the corner stone of systems engineering in an automated (without faculty) environment. Whatever digital teaching method is used (placing the basic material, power point presentations, recorded lectures, or synchronous classroom presentations), online courses have enabled students to transition from traditional face-to-face classrooms to a virtual environment. The traditional lab experience in the past has been conducted in physical facilities where through recursive experimentation (trial and error), the practical application of the

techniques and processes learned in face-to-face lecture based learning are experienced by the students. Another approach to this recursive experimentation is to have project teams visit a specific customer or work on some manufactured situation to solve. In the digital environment, the opportunities for practical hands-on experience and/or site visits are limited, as indicated in the graduate level systems engineering program review undertaken as part of this thesis. What this proposed approach hopes to achieve, instead of a hands-on trial and error, is to get the students to articulate their proposed process, techniques, and approaches learned in class to a specific example, and to get feedback in a discussion forum from fellow students. Rather than experience a trial and error approach based on direct observation of the physical experiments where the students see the success or failure of their efforts, the comments of their classmates will expose the strengths and weaknesses of the logic of their approaches to similar SE problems. By requiring each student to submit an approach to the problem and respond to their classmates, no student will be able to be a passive learner.

In general distance learning programs are not significantly different from the traditional face-to-face experiences. The difference is instead of lecturing to 30 students arrayed in front of the teacher, the students are dispersed across the internet. The courses are using the same presentations as face-to-face classes, which have changed little over the last decades. While traditional programs have a tutor working with the student providing immediate feedback and removing difficulties or roadblocks, the internet and distributed learning allow classes to provide real-time automated feedback on tests and quizzes and facilitate targeted review of misunderstood material. Full-time student support from a resource center or help line can help with either the enabling technology or the subject, which is similar to the graduate student (tutor) sessions. Centralized support from a single location can lower the support costs for a larger student body when compared to the hands-on sessions. One of the difficulties of distance learning is when the students become frustrated and demoralized by a roadblock, the roadblock removal process can be difficult. By using a discussion board versus a physical exercise, students avoid the potentially disruptive roadblocks.

C. USE OF GAMES FOR DIGITAL LEARNING

In trying to instill analytical skills, militaries worldwide have used war games since the early 1800s in some form. Modern chess, beginning in 1644, is another recognized tool for building analytical skills. These games develop a cognitive action and reaction, and attempt to focus on analytical thinking rather than memorization of facts. Just as digital technology has allowed immediate responsiveness in tests and quizzes, games can be used to evaluate simple binary, right or wrong, answer games such as math problems. The use of games or simulations for critical thinking skills may represent that next generation of learning opportunity. In the opinion of this author, the link between improved student performance, learning games, type of learning activity and total time invested has not been fully explored. Until the total student time invested between games and academic improvement is established, the use of games will continue to be constrained.

Another approach for digital and distance learning is the integration of games into the curriculum. The current research in using digital games as learning tools date to the 1990s when students used games, such as SimCity©, to understand the roles of system enablers and system constraints. As technology advanced, more specific games designed to engage students to learn basic math skills and reading have been employed. These games have been used in a wide variety of roles and locations, both academically and specific skill areas (i.e., auto-mechanics or aircraft pilots). To be effective, the games and online learning tools should allow students to repeat sections where they are having trouble. The games also afford additional examples and exercises to reinforce problem areas. However, these games are limited in that they have definitive right and wrong answers (and are not well adapted to analytical problem solving). DOD's Advanced Distributed Learning Initiative (Raybourn, 2005) and related efforts have used automated/digital games to create repeatable simulations where students are placed in specific situations and include post-game after action reviews. The Defense Acquisition University (DAU) has leverage digital games to enhance acquisition of professional skills as both fun quizzes and to highlight learning weaknesses (Sanchez, 2009). Air Force and others military entities have developed simulators to make specific situation reactions

almost automatic. However, these games are tailored for specific missions or needs and are not creating and evaluating the critical thinking skills of the players (Catanzano, 2011). If the player encounters a specific situation, the appropriate re-action becomes instilled. In this manner, the games have been successful. If the player turns the ignition but does not hear the spark plug engage, the player will know or suspect that the battery is dead. If the player sees the enemy fighter perform a specific action, the player can project the enemy's intentions and react accordingly. These sorts of simulations or games work very well in their limited environment, but statistical evidence that the skills leverage to other situations has not been demonstrated (Egenfeldt-Nielson, 2006).

When the military does war gaming with two opposing teams, the games are outlined, and the action and re-action of the teams becomes the dynamic part where the learning takes place. In the DOD environment the two opposing teams are referred to as the blue and red teams. The game facilitator manages the actions and records the logic behind each team's or participant's actions and then in post-game analysis evaluates the game for effectiveness (McLarty, 2012). The interaction between the moderator, team members and the opposition are more important than the game setup, whether the games are table top exercises or digital simulations.

Dr. Alicia Sanchez (eLearn Chat, 2012) indicated that even when she tries to anticipate expected team actions or reactions, she is constantly surprised by the diversity of the responses. Dr. Sanchez further articulated that when the responses are fully explained there is almost uniform consensus of what is the winning move among the games' players, even if it was unexpected. The takeaway was that the learning moments were not in the playing of the game itself, but in the interactions and discussions of the particular moves. In a physical laboratory experience or a customer project team, the learning is not in setting up the experiment or setting up a facility, but in understanding what works or does not work and why. For the M*A*S*H Systems Engineering Exercises, the learning will in small part be in creating a response to the exercises, but in large part will be in the discussions and interactions following the individual exercises.

While digital or online games have shown limited capability to develop critical thinking skills in participants, these games do motivate the students to spend more time

on the subject than they might have done otherwise. A game was designed and a developmental prototype was created; however, it became evident that the M*A*S*H simulation would be more game related to maximize the game metrics and less focused on the embedded systems engineering learning points. The underlying concept of the M*A*S*H simulation was to show how using logistical information to understand what is occurring in the M*A*S*H unit. When the prototype was demonstrated to a select group of reviewers, the response was disappointing. For selected disciplines, it might have been useful to consider, however, for the diverse student body, the activity was more "game" and less "learning" and further development was stopped after significant effort. The game logic is outlined in Appendix C. Even if the fully mature game were integrated into the curriculum, the scoring for the game would be subjective and the ability to extend the game lessons to the physical world would be difficult to quantify.

Other research efforts have shown that game based learning is equally effective across various platforms. (Dziabenko, Pivac & Bouras, 2003) This research effort demonstrated that games or simulations run off a single web server on any number of platforms (IPAD©, Laptop, Desktop, distance, and other environments) are equally effective. If the M*A*S*H simulation had been more fully developed as a learning tool, this research would support the hypothesis that the M*A*S*H simulation could have been carried forward on other platforms with nearly equal success.

D. BRINGING THE PHYSICAL LAB TO STUDENTS

Another concept to engage the students was to bring the hands on experience to students by distributing Lego Mindstorm© Kits and have students walk through a "Mission Creep Exercise" with associated discussions. The concept is more fully articulated in Appendix B. The concept was to have the students walk through a series of systematic enhancements of the Lego© robot. While concept is more hands-on (requiring mechanical inclination and basic software competency) than the M*A*S*H alternative, the ability to integrate across the introductory course and/or curriculum as a whole proved difficult. The result was a two-semester lab experience where the systems engineering points are explored during the Lego© exercises and discussions. A

complication of the Lego Mindstorm© Kits is the potential for the students who are not mechanically and software programming inclined to become frustrated and discouraged, and effective help may not be available via the web. Another complication of the Lego© approach is that it would be difficult to convey via distance mechanisms the recursive learning of trial and error while creating a working prototype robot. The final Lego© exercises risk is that the students focused more on the mechanical and software components of the exercises, and not on the system engineering applicability of the exercises. This risk is similar to the mastering the gaming components of a game or simulation versus the educational learning points.

III. A PROPOSED SOLUTION FOR A REINFORCING SYSTEM ENGINEERING LEARNING OBJECTIVES

Throughout this thesis, the term ‘cultural reference’ has been used to describe the theoretical framework that the students will be applying their system engineering skills. So as to keep the exercises fresh and a level playing field for all students, the movie, television show or story that all the students will have only a superficial knowledge of will be used. In the selected story, there are always details that help fill in the situation and background that are rarely described or explained, but the reader or audience has to take as reality as the story unfolds. This thesis will have the students try to fill in the blanks or details of that situation or setting, which is similar to how system engineers know the mission objective or purpose, but not the individual steps needed to accomplish that goal.

Although the cultural reference methodology for these exercises is generic for reinforcing system engineering learning points, the M*A*S*H exercises specifically are used for simplicity in explaining the approach below. This chapter is presented in three parts. The first explains the logic of the exercises. The second part walks through how the exercises reinforce the SE learning points. The third part walks the reader through how the exercises reinforce the learning process in general.

A. EXPLANATION OF THE M*A*S*H EXERCISES

To make digital based learning effective, it needs to engage the students, prevent passive learning, provide near real time feedback, keep the students’ interest, which will collectively lead to more thinking time invested and thus more learning.

Using the “M*A*S*H”© television program as the conceptual template for the exercises, and a series of web based discussion board readings and responses, the students are guided through an analysis of the M*A*S*H 4077th from a systems perspective. There are currently 13 different exercises (see Appendix A), with different follow up questions (referenced as phase 2 questions) that may be chosen by each faculty member to reinforce the particular class’ learning points. While the exercises have been

aligned into a single introductory level class, the exercises could be used by multiple classes. All the exercises start with a hypothetical letter home from M*A*S*H 4077th company clerk, Walter "Radar" O'Reilly. The letters provide some guidance for a systems engineering question that the students will provide a short (200-300 word) or long (500–600) word initial submission with comments on at least two other students' submissions (providing immediate feedback). The exercise continues with a follow-up question to tailor the learning experience. The second-phase question asks for a shorter submission and comments on two other classmate's submissions. Requiring each student to formulate his/her own response and then comment on other students' responses will encourage active participation and expose the students to alternative perspectives incorporated in the diverse backgrounds of their classmates. The students' diverse backgrounds will result in a multitude of different approaches to each question and varied responses to the submissions. It is expected that the classmates' comments on each other's approach will show the strengths and weaknesses of each approach without the student having tried each process individually.

Time is a constraint for the class, professor, and students, so although there are multiple exercises that may fit well with in the introductory classes and exercises that can span the curriculum, the individual faculty member will choose specific exercises to reinforce the learning points he/she feels need additional awareness. It is not expected that any professor will use all or even most of the exercises. Yet the professor will have the opportunity to integrate as many or as few as he/she likes into the core curriculum and the introductory courses. Although several courses may reuse the same core exercise, the additional time and course materials reviewed during the particular quarter will influence the students' responses. Asking the student to define a stakeholder at the beginning of the program, middle of the program and upon graduation from the systems engineering program will evolve and change, enabling professors to proceed without worrying about overlap in exercise selection across the eight quarter program.

It is expected that each professor will choose one of the follow-up questions, but there is nothing prohibiting having the students answer several of the follow-up questions in sequence. The professor could also divide the class into groups to answer different

follow-up questions. Each exercise and associated Phase 2 question is expected to take a week. Although if multiple Phase 2 questions are used sequentially within a course, it would stretch out the exercise beyond the one week envisioned per exercise. Each of the sample exercise includes a methodology discussion at the end for the professor to review and a guide for writing future sample letters for other cultural references.

Although the “M*A*S*H” series aired from 1972 to 1983, the episodes are still in reruns today. The students’ familiarity with the “M*A*S*H” program or an actual Mobile Army Surgical Hospital (MASH) is not needed. The use of the program is intended to provide a common reference for the students to keep the exercises interesting. The use of this reference will also demonstrate that many systems engineering principals that were present in the 1950 Korean War are still relevant today. By selecting this historical setting, no student will have an advantage on any other student in applying the SE learning points to the exercises.

By using a web based discussion board and compelling each student to do each exercise and then comment on other students’ responses, the students are forced to be active participants and to think about the relevant systems engineering tasks. If these exercises were done in a classroom setting, not everyone would be able to share his thoughts, a problem which is avoided by putting the exercises on the web platform. By keeping the assignments to either 200-300 words or 400–600 word answers and shorter word Phase 2 responses, will ensure conciseness in the students’ answers. The scoring of these exercises is mostly subjective, but a consensus will be discernible based on the uniqueness of comments or the submission with the most comments. The number of words is less important than the content of the material. Determining if the initial submissions or the students responses to other submissions is more educational is an area for future research. The initial presumption is that the students will spend slightly more time and achieve more educational value by reviewing their classmates’ submissions and comments, than in formulating his/her own initial submissions and comments.

Several studies reviewed (Ambrose, Bridges, DiPietro, Lovett, & Norman, 2010), indicated that the more mechanisms that involve the students in the course material, the more likely it is the material will be internalized. The lecture and class assigned readings

are two means, the tests and quizzes are a third mechanism. Student interactions either in a classroom or on discussion boards, , is the fourth mechanism for teaching. Use of games or simulations could be a fifth; however, for the higher level analytic exercises, the results have been limited (Young, 1997). With designing a game is beyond the scope of this thesis, the use of the discussion boards with the associated student interactions is the proposed alternative to a physical laboratory or team project to reinforce the critical systems engineering learning points. Higher level thinking is encouraged when students are both challenged and can leverage past experience or examples (Young, 1997).

B. HOW THE EXERCISES REINFORCE THE SE LEARNING POINTS

The specific exercises are broken out in Appendix A to facilitate their extraction for use by each professor. Table 1 is a systems engineering outline with associated exercises for quick reference. A discussion of how each exercises covers the associated learning points follows the table.

Table 1. Systems Engineering Steps Alignment with M*A*S*H Exercises

1) Stakeholder Requirements	What is the CONOPS that requires a materiel solution: Exercise 1 asks for operational requirements and Exercise 2 is identifying the stakeholders.
2) Requirements Analysis	What are the measurable and verifiable requirements: Exercises 1 and 8 are requirements both at the high level KPP.
3) Architectural Design	Choosing an analysis of alternatives to meet requirements: Exercise 3 and 7 are breaking the M*A*S*H unit into component parts which is the architecture of the camp.
4) Implementation	Developing the supporting systems to meet the requirement: Exercise 4 addresses implementation by asking the students to address the data passing between the elements.
5) Integration	Putting lower level elements into the physical architecture: Exercise 4 addresses data management integration while Exercise 5 is the physical layout of the camp.
6) Verification	Confirms the elements meet the designed specifications: Exercise 8 identifies metrics to ensure the camp achieves the design as required (built to specifications).
7) Validation	Does the solution meet the military needs:

		Exercise 9 is assumption identification which feeds the military needs. Exercise 10 concerns market surveying, which goes to how find and evaluate alternatives and ensuring the COTS product meets the military need.
8)	Transition	Transition is the fielding or modernizing of the actual outfit or system: Exercise 6 is a linear program to model the supporting logistics needs of the M*A*S*H unit. Exercise 11 covers modernization and Exercise 12 identifies programmatic concerns, such as earn value management.

The first step in any system development is identifying the mission objective and the system requirements to meet that objective. Part of identifying mission objectives is to understand who the stakeholders are and what their interests are. Within the Department of Defense (DOD), the analysis of alternatives (AoA) and the Joint Capabilities Integration and Development Systems (JCIDS) will result in a material solution analysis (MSA) which includes system requirements and/or identifies the needs that the program or system is intended to address. This first step is broken apart as Exercises 1 and 2 and requires identifying the objectives and stakeholders who are involved in a given system. Although the DOD systems engineers are frequently handed the overarching system requirements and lower level system requirements, these two exercises are intended to enable the systems engineer to walk through the process and to understand the implicit assumptions that went into requirements that he/she is being asked to meet.

By having the students extract the mission objectives from an existing system (Exercise 1a—Mission Objective), the M*A*S*H 4077th, the students will see the end product and reverse engineer the requirements normally provided. This reverse engineering includes identifying performance metrics (Exercise 1b—System Metrics) and then trying to quantify what are the threshold and objective performances they wish to measure (Exercise 1c—Threshold and Objectives). The submissions will provide insight into the students' thinking with their classmates providing feedback demonstrating both the strengths and weaknesses of each students approach and logic.

Identifying stakeholders (Exercise 2a—Stakeholders) is an important exercise for any system development and those stakeholders who may require revisiting the KPPs/KSAs for the system (Exercise 2c—Stakeholder Concerns). A learning point of the Exercise 2c is that if the stakeholders' concerns are not linked back to the KPPs/KSAs, then maybe they are not primary stakeholders. In the DOD system acquisition and development environment, these are iterative processes of going back and forth between requirements, performance metrics and the various stakeholders. By having the students do each exercise individually, the diverse backgrounds of the student body will emulate the interests of the various stakeholders. The multiple entries from the students will also compress the normal give and take that goes into refining the metrics.

Instead of having the students come to consensus of an explicit list of stakeholders, the students are asked to identify the logic behind inclusion and exclusion of specific stakeholders (Exercise 2b—Included and Excluded Stakeholders). By including the theater's road system and organic infrastructure as potential stakeholders (Exercise 2d—Non-military Stakeholders KSA), we are addressing the system maintenance and sustainment elements required for any system. The goal is not to let the students get bogged down in a specific list selection, but to expose the students to the multiple perspectives of their fellow classmates as the learning component. This exercise will also compel the students to acknowledge that no product or solution is perfect and going to serve all stakeholders perfectly. The intent is to ensure that the students consider the interfaces to the systems outside the immediate DOD organization (i.e., unit, military, theater, region, country, and society) and what their perspective metrics may be (Exercise 2d—Non-military Stakeholders KSA). Exercise 2d combines stakeholder and requirement components into one exercise, with an additional twist of how systems engineers incorporate the lower level concerns of the stakeholders, who may not be present or aligned in the higher level KPPs/KSAs. Exercise 2d may also help students recognize that not all stakeholders will have KPP and KSA that address their needs.

Once the military identifies that a physical weapon or information system that fulfills a military requirement, a process to break down the system into an architectural design and component parts commences. There are various mechanisms to deconstruct

any system and the exercises replicate this diversity by looking at the process flow (reliability block diagrams in Exercise 3), the data processing needed and used within and outside the system (Exercise 4), the physical camp layout (Exercise 5), the logistical support requirements (Exercise 6), and the functional decomposition (Exercise 7). Collectively these exercises lead to a series of questions that transition into how a systems engineer will design, integrate and implement the architecture into a working system.

Exercises 3 and 4 both start with a reliability block diagram (RBD) describing a generalized M*A*S*H process from patient induction to discharge. The Exercise 3 focuses on risks to the system by investigating single points of failure (Exercise 3b—Single Points of Failure), human factors (Exercise 3c—Human Factor Risks), risk mitigation (Exercise 3d—Risk Mitigation), and creating a risk matrix (Exercise 3e—Risk Matrix). Each of these risk areas are addressed in multiple classes within the systems engineering program. The diversity of the students will result in multiple risks and risk analysis approaches. As no one approach is better or appropriate in all cases and all situations, the learning point that the multitude of risk evaluation approaches articulated should be enlightening. There are multiple exercise options since each risk type is unique, with its own impact, mitigation and classification approaches that are all rather subjective. The best way to reduce risk in a system is to add redundancy, which also adds complexity. This additional complexity impacts costs for design, building and maintaining. Implicitly the program manager and systems engineer should ask whether additional costs are justified for the level of risk mitigation being added. This risk mitigation compared to cost trade space and KPPs/KSAs requirements is not addressed in any particular exercise.

Exercise 4 focuses on the architectural design through the data processing lens. After creating a RBD and identifying what data elements are passed between the blocks. Phase 2 questions address how a systems' internal data is being passed between elements and can be used for logistics purposes (Exercise 4b—Notification of Supply Requests), how the data can be used for performance monitoring (Exercise 4c—Data Passing as System Monitoring) and how external clients would use the data (Exercise 4d—Data

Passing to External Customers). Using the 1950s M*A*S*H data processing practices as shown in the television program as a baseline, the students are directed to identify how to bring it into the twenty-first century (Exercise 4e—Modern Logistics Management). Frequently, organizations follow processes and procedures that were originally created in different times and get stuck on doing things the way it has always been done without objectively revaluating the entire process. Exercise 4e asks how to digitize the data processing, while also giving the students the leeway to redesign the process and break down historical precedence.

The M*A*S*H decomposition can also be viewed through the logistics support requirements and is addressed in Exercise 6—How Many Trucks. The exercise uses a simple linear program designed for the System Optimization class. By walking through all the logistic constraints and requirements, the students are exposed to a classic military logistics approach. Through identifying constraints (Exercise 6b—Additional Constraints) and performing a sensitivity analysis (Exercise 6c—Sensitivity Analysis) the students will better understand systems optimization. Although the exercise focuses on the M*A*S*H logistics needs, the same lessons of constraints and flexibility tradeoffs can be applied across the systems engineering process. While the Korean War M*A*S*H unit has a classic logistics support design, the students are invited to investigate alternative support profiles in the program modernization Exercises 11a and 11b.

Functional decomposition of the M*A*S*H unit using hardware, software, people and data to matrix against the implications on cost, schedule and performance is addressed in Exercise 7a. Exercise 7b—Performance Parameters and Exercise 7c—functional area impacts are either silos (one functional area) or cross area performance (one criterion) and can be allocated by student to review each area or let students choose the silo or performance area to consider against. The implicit learning point is that focusing on requirements and functional allocation too early in a system's development process can lead to sub optimal solutions because of early architecture, technology and process decisions that can create artificial constraints on the solution. Providing both Exercise 7b and Exercise 7c will enable the students to connect the interdependencies between functions and performance. In this manner, students will recognize that a

balanced approach to entire systems engineering development, considering the trade space between the appropriate functional areas, is as important to the solution as its performance. A system engineer should recognized that a solution that relies too heavily on any particular element such as maintenance, consumables, spare parts or manpower support for hardware or software may result in an unaffordable solution.

Exercise 5 is intended to break the architectural design of the M*A*S*H unit from the risk, data, logistics and/or functional perspectives into a physical layout of the camp. While the previous exercises were abstract representations of the camp, this exercise is a model of the actual camp. The Phase 2 (Exercise 5b—SWOT Analysis of the Layout) is a strength, weakness, opportunity, and threat (SWOT) assessment of the camp. Although weaknesses and threats are risks that are addressed elsewhere, the strength and opportunity are an early assessment of the prototype design to see how well the proposed design will meet the mission objective and requirements. By designing a physical layout, the students will recognize that even when everything needed is present, if the layout is not logical, the system may not be suitable.

Once the M*A*S*H unit or any system has undergone its architectural design process and is prototyped, the system verification will to evaluate how well the system is meeting the KPPs/KSAs. When considering the lower level stakeholder concerns, the exercises implicitly ask the students to identify which requirements and how to measure them as part of the process. As part of the architecture design, the interim performance metrics that feed the top level performance objectives are considered and the ability to measure them should again be considered in the design. By asking the students to identify five measures of effectiveness that support the higher level requirements (Exercise 8a—Key Performance Parameters), we explicitly break out the process that would have evolved earlier in the systems development. The weighting of these requirements (Exercise 8c—Ranking & Weighting the metrics) and the evaluation of the trade space between these requirements (Exercise 8d—What Can Be Sacrificed) are traditionally processes involved in an analysis of alternatives and in the formal testing and evaluation process. The students' discussion of their logic when verifying the performance metrics and trade space among the students provides the learning. Inevitably, every program will

trade performance between individual requirements to find a local optimal solution that is considered the best for the mission. Yet, as those decisions generally are a result of cost, technology readiness, schedule, operational constraints and other elements beyond the systems engineers' direct control, this trade space discussion is left generic in Exercise 8d.

Whenever a metric is designated for any purpose, there are inevitably mechanisms that can maximize the performance metric but fail to meet the true system objective. Instead of trying to get the students to justify what lower level performance metrics they like best and why, the students are directed to try to identify how someone can game the system (Exercise 8b—Winning a 4 Day Pass), thereby maximizing the metric but missing the mission effective objective.

Once the system has been determined to meet the high level KPPs/KSAs and lower level implicit requirements, the system validation process will again revisit the question of whether the system is meeting the mission objective and requirements. In the M*A*S*H series, the unit was operationally effective in meeting the objective of saving lives, so traditional system validation is not a relevant exercise. By asking about what assumptions the students made while doing any of the exercises (Exercise 9a—Assumptions), the intent is to get each student to recognize that his/her individual perspective is based upon unconscious assumptions when building any system. By asking the students to adapt to an underlying assumption change (Exercise 9b—Change Assumption), the students are preparing for the fact that every system will need to be flexible to overcome unforeseen difficulties.

System validation within the DOD community typically refers to evaluating the system to determine if it is meeting the original mission requirements. In this case, by researching if a commercial off-the-shelf (COTS) solution (Exercise 10a—Market Survey) meets the military's needs, the students are instructed to evaluate the developed system against those system requirements. Market research is frequently associated with investigating business opportunities where the company can make money. In this case, the students are asked to outline how they would conduct such a market research. The goal is to use market research to take existing commercial systems and apply them in new

and cost effective means to meet the DOD's needs. Undertaking a market research to determine if a commercial solution could meet the DOD needs is similar to evaluating if the M*A*S*H unit is meeting the military's needs. Exercise 10b— Militarization of COTS, demonstrates that evaluating not just the financial and performance metrics when adapting commercial products to the Military's needs is important. Bringing the system into the military environment is equally important to its eventual demilitarization and eventual retirement. Exercise 10c— De-militarization of System, is a component of any systems life cycle that systems engineer needs to keep in mind when developing the initial system. Although demilitarization of a M*A*S*H unit may not seem like a big deal, between privacy concerns and modern medical waste issues, this issue does justify its inclusion in the exercise options.

Once a system has been built and tested and deemed appropriate for the DOD's use, the systems engineer will be involved in transitioning the system to the customer, which includes fielding, logistics and ongoing support. When using COTS products, by the time a system is finishes testing, some components are already facing obsolescence and material shortages. As a result, systems are undergoing some modernization as soon as the first system deployments are beginning. While modernization can force change and adaptation, organizations and entire systems may evolve as a part of modernization, and/or as part of continuous incremental improvements. System spiral development or evolutionary improvements lead into how the students could implement the changes (Exercise 11a—Program Modernization) and a vision of where the organization is going. Exercise 11b—SWOT Analysis of Modernization, uses the SWOT construct to compare the Korean War M*A*S*H, the student modernized M*A*S*H version and modern medical facilities. Exercise 11c—Do We Need a M*A*S*H, again revisits past assumptions in the light of new environments, since new technology means the forward aide stations are much more capable and portable than in previous generations, and the improved evacuation systems mean the wounded may be transported much further and faster than previously imagined. Although modernization, SWOT, and assumptions are included elsewhere in these exercises, this modernization, change and adaptation context was created to address system evolution and system suitability learning points.

The physical systems engineering laboratory is about designing and creating a specific mission effective solution. Systems engineering is not just creating a system or product, but is also managing the processes and resources to achieve the objective. As systems engineers, we make decisions between getting things done quickly (time), cheaply (cost) or correctly (quality), and be those decisions exist with M*A*S*H or in our professional lives. The students are asked to evaluate what tradeoffs are being made (Exercise 12a—Time, Cost Performance Trade Offs). The intent is to ensure that the students understand what trade space items are being considered and the associated impacts. By recognizing what trades are being made as an impartial observer, the students are then invited to recognize that those same tradeoffs are occurring everywhere (Exercise 12b—Real World Trade Offs). The intent is not to dive into minutia of the issue, but to get students to understand that these tradeoffs are occurring naturally and constantly in our professional and personal lives.

Another aspect of program management the systems engineer must understand is cost as independent variable (CAIV) and earn value management (EVM). Although CAIV was included as Phase 2 option in Exercise 8d—What Can be Sacrificed, this specific exercise was created to focus on this critical learning point (Exercise 13a—Cost as a Constraint). The programmatic complications of actually trying to meet a requirement are addressed with the performance evaluation (Exercise 13c—Performance Evaluation) and indirect considerations that are not originally considered as requirements (Exercise 13d—Indirect Benefits and Considerations). These indirect considerations are similar to tertiary shareholder concerns (Exercise 2d—Non-military Stakeholders KSA). It is included here again because it fits in well with the exercise. The EVM exercise (Exercise 13b—Earned Value Management) is the driving motivation of the exercise and gives the students the opportunity to discuss the EVM process.

While the above describes how the exercises cover the systems engineering process, there are a virtually unlimited number of additional exercises that could be created to explore additional learning points in more detail. Some of the additional learning points that are not explicitly included, but could be worked into the class discussions, are included and discussed in Appendix D.

C. HOW THE M*A*S*H EXERCISES WORK TO SUPPORT LEARNING

How Learning Works by Susan Ambrose gives a template that can be used to evaluate the M*A*S*H exercises. The first consideration when trying to teach any new topic, is building on a common knowledge foundation. Part of encouraging motivated learning and knowledge transfer is to link classroom based lectures with the exercises. Since each service branch has a medical services group and individually every person understands the basics of generic medical care, the M*A*S*H medical analogy should be effective as an everyday example. Additionally, the M*A*S*H television program can fill out the generic understanding of the referenced system engineering environment. This commonality will give all students relatively equal starting points and provide a non-intimidating climate to demonstrate the system engineering learning points. By demonstrating the system engineering processes within the M*A*S*H context should help students put the systems engineering learning points into another context as reinforcement. M*A*S*H as a historical reference helps students evaluate the entire lifecycle of the system. The exercises have specific intended learning points and specific follow on phase II exercises intended to align with the classes and lectures. The individual exercises are sequential, which permits the laddering or scaffolding of specific skills or techniques in small increments without the intimidation of performing an analysis of the entire system engineering process all at once. All of the exercises permit the faculty member to tailor the phase II questions to address learning gaps that may be evident in the Phase I student submissions and responses or comments or reinforce specific topics.

Another advantage of this approach is that students cannot be passive or anonymous. The diversity of the students should permit the multiple strategies to each problem, and permit the students to feel safe since no one approach or answer is going to be the right answer. The experienced or master system engineers will subconsciously consider and rule out various approaches without fully articulating the reasons for the excluded options. By having the multitude of answers, many of those excluded approaches hopefully will be demonstrated, even as they are eliminated from further consideration. Fellow student comments will provide immediate and targeted feedback,

which will give quick victories and positive reinforcement that will support the learning process. The multiple of approaches or strategies presented by the students and the associated comments should help understand that no single answer is right or wrong (safe class climate). By keeping the exercises to one page, the submissions are focused on the strategy to address each problem, and avoid the risk of the students wasting time on off topic, detailed, or deep dive discussions. This risk of spending time on non-critical issues is similar to the gaming risk where students focus on maximizing a games score versus understanding the system principals. The Lego model alternative has a similar risk where students focus on actually getting the robot fully working (coding or design) and missing the system engineering principals the exercises are intended to convey. This focused approach is considered a strength of the M*A*S*H exercises. Because the exercises are short, the level of challenge will not be intimidating to the novice system engineers, but be sufficiently difficult to enable the journeyman system engineers to demonstrate a more comprehensive implementation of the learning objectives. Being small, the exercise breaks the content into component skills and tasks while not overwhelming the students.

Ideally, the fellow students' discussion would reinforce the positive learning points, and demonstrate shortcomings in various submissions in a non-threating manner. Some students will want the faculty member to weigh in on submissions during the discussions so an optimal approach is shown. The advantage would be that the comments would reinforce the learning objectives. However, the disadvantage is that the faculty's comments might stifle individual or class reflection on the optimal approach and potentially isolate a valid but outlier solution and risk the collaborative discussion culture of the class. To reinforce the learning objectives, a moderator (other than the professor) could fulfill the steering role and reduce the professor workload. An alternative for providing feedback would be for the faculty member to provide group feedback by presenting a synopsis of the relevant class learning points during the following class period. This would highlight what are critical points, while not inhibiting the open discussion. The exercises were designed to reinforce course learning objectives, but also provide insight into potential gaps in the student's knowledge or comprehension. Any gaps can be addressed by direct faculty/monitor feedback during the discussion, changing

the Phase 2 question, or during the group feedback session during the next class. If the discussion was thorough in its breadth, the class can move forward without additional class time.

An area for future research may involve how to spot learning gaps in the students' responses and how to address those missed learning points.

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IV. INTEGRATING THE EXERCISES INTO THE CURRICULUM

This chapter is presented in five parts. The first section reviews the case study learning approach. The second section discusses the selection of a relevant cultural reference for extracting system engineering learning points. The third explains the logic involved in creating the exercises with system engineering learning points as the objective. The Fourth section is how to implement them into a SE curriculum. The fifth section is a recap of the creating the steering letter guidance for each exercise, which is also in the appendix after each exercise.

A. THE LEARNING APPROACH

In traditional case studies the students read a written case, analyze the strategies employed and discuss what worked and how it could be adapted to other environments. System Engineering is about creating a solution to a problem or satisfying a need. Because the Systems Engineering process includes identifying the context of the solution, the stakeholders or actors involved, and generating alternatives to address to situation, a full case study narrative is counterproductive for the outlining the problem. So instead of articulating the entire situation, we look to cultural references to explain the situation and let the students fill in the missing components that the movie or television show does not delve into as part of the story. By using different references, the exercises will be continually revised and new. Each cultural reference includes different challenges, strategies and actions taken by the character so the purpose of the exercises should be unique and dynamic for future classes. In traditional case studies the solution or outcomes are evaluated and lessons learned are identified. These case study exercises are not focused on the particular solution or outcome involved in the cultural reference but the system engineering learning objectives implicit in the processes, procedures and settings that enabled that end result.

B. SELECTING A CULTURAL REFERENCE

The cultural reference is the setting and environment that a movie, book, television program or play is set in. The choice of the reference is going to shape the

nature of the exercises, so look for something where you have at least 6 to 8 central identifiable character or roles where each character would represent a different stakeholder within the system. The next characteristic to look for is a competitive situation where tough decisions and consequences are viewed as significant. Consequences of wins or loses, success or failure, living or dying or ruin are dependent on the system so that trade spaces can be identified. For these exercises we need a steering letter or discussion point of view to frame each exercise. The frame of reference is not a central character. Think of a trainer, doctor, secretary, janitor, clerk or some other character that could naturally be present or aware of all aspects of the system to either facilitate or initiate the exercises. If the perspective chosen for the exercise facilitation would be considered a candidate for a leading actor or actress role in the reference, it probably is not a good choice, because they would not naturally have a holistic understanding of the entire system. This facilitator would be writing a fictional account of some aspects of the system to a family member elsewhere to fill them in on their lives, even if we never see the person doing so in the cultural reference.

C. CREATING THE EXERCISES

Each of the exercises outlined in Table 2 and the guidance for creating new exercise in Table 7 use the same facilitating perspective to extract elements of the system for analysis. Each exercise focuses on a specific learning point for that exercise and some guidance on what to look for inclusion into the steering letter home for the different learning points of each lesson or exercise. Where each stakeholder will have their own requirements and associated metrics; when asking about stakeholders, the letter can talk about the stakeholder's requirements, or the requirement's performance metrics, which can be used to infer to the other area. The letters will generally include one obvious component to the answer, but frequently not the most significant answer, and tertiary or secondary answers to facilitate a larger perspective solution or answer from the students. People or groups are frequently thought of stakeholders, but we want to stretch the student's perspectives so each exercise has a reference to a non-person stakeholder. Each topic then has a secondary question which can vary depending on a particular classes dynamics to push the students to delve a little deeper in a particular direction within each

learning objective. Each question was originally intended to be 400–600 word answers with 200–300 word secondary questions. In the compressed format of a single class, and to address the constraint that each students breadth and depth of experience to draw upon for each exercise during the early course in the program, the recommended approach is to have each student write a 200–300 word answer to initial submission and a 100–200 answer to the secondary question. However during the course of the program, each student is expected to answer a certain number of the questions with a longer (400–600 word) submission based on their personal experience and prior knowledge that can be leveraged. If a student has a lot of experience with testing, the system validation answers should be longer, if the student has a lot of experience with requirements generation, the requirements and metrics should be a longer answer. Each student should ask themselves which of the 2 or 3 exercises or topics they will push themselves on. In the process, the answers and response on other student's submissions should require less time (because many answers are shorter and thus quicker to review). Each student should provide their own submission for every exercise even if they are less comprehensive answers then their classmates. Although each exercise has a follow on question, some of the follow on questions would not have been covered in the introductory course but are left as examples of how the exercises can be stretched in different directions.

D. INTEGRATING THE EXERCISES INTO THE CLASSES

For the initial application of the cultural reference case study analogy, the following exercises were created uses the M*A*S*H television show as the frame of reference.

Table 2. Exercise Learning Objectives

Exercise	Title	Subject	Question
1a	Mission Objective	System Requirements	What are the Operational Requirements for the M*A*S*H 4077th?
1b	System Metrics	Measuring KPPs	How will the Operational Requirements be measured?
1c	Thresholds and Objectives		Identify a threshold and objectives for 2 KPPs and how you determined

Exercise	Title	Subject	Question
			those values.
2a	Stakeholders	Stakeholders	Who are the stakeholders of the M*A*S*H 4077th? What are their interests?
2b	Included and Excluded Stakeholders	Who are the customers	Chose a stakeholder from another student's list that should have been included in your list. Identify a stakeholder from another student's list that should not be considered a stakeholder and why?
2c	Stakeholders Concerns	KPP/KSA allocation by Stakeholder	Choose a stakeholder on your list and identify which KPP/KSA from Exercise 1 they should be concerned with and why?
2d	Non-military Stakeholders KSA	New stakeholder KSAs	Choose two stakeholders with at least one of which is not in the military from your list or that of another student. Identify what his/her M*A*S*H 4077th requirements and associated metric should be.
3a	Systems Engineering Deconstructions	Reliability Block Diagram	Create a single page block diagram of the processes with the M*A*S*H unit as you see them.
3b	Single Points of Failure	Bottlenecks	Identify any single points of failure and what steps can be done to mitigate this failure mode or bottleneck.
3c	Human Factors Risks	HSI risk mitigation	Identify what steps you could take if the flu hits the camp and half your staff becomes sick.
3d	Risk Mitigation	Redundancy contingencies	Identify what you think is the riskiest (likelihood and consequence impact) task and what you could do mitigate it.
3e	Risk Matrix	Quantifying the risks	Choose your top five risks and place them on a Risk Matrix. Explain why?

Exercise	Title	Subject	Question
4a	Systems Integration	Data Processing	Identify what information is passed from each block to the next.
4b	Notification of supply requests	Event triggers within the system	Which data items could be leveraged to let Radar know how many supplies to order and when to do so?
4c	Data Passing as system Monitoring	Performance Monitoring	How could you use the data to monitor the camp's performance against internal metrics or against system requirements?
4d	Data Passing to external customers	External Interfaces	Which data should be transmitted to external customers (outside the M*A*S*H unit)?
4e	Modern Logistics Management	Digitalization of the Processes	Describe the process of how you would digitize the processes and how would it improves the processes.
5a	Camp Layout	System space allocation	Create a single page layout for the M*A*S*H unit.
5b	SWOT Analysis of the Layout	Strength, Weakness, Opportunity and Threats	What are some of the strengths, weaknesses, opportunities and threats of the camp layout?
6a	How Many Trucks	Linear Programming	How many trucks should be bringing supplies to M*A*S*H 4077th?
6b	Additional Constraints		What adjustments would you make at ICOR to ensure the equipment gets to M*A*S*H 4077th?
6c	Sensitivity Analysis		What adjustments would you make to address each of the above items?
7a	Functional Decomposition	Hardware, Software, Data and People	Do a functional decomposition of the M*A*S*H 4077th including hardware, software, data and people.
7b	Performance Parameters	Cost, Schedule & Effectiveness versus functional areas	Discuss how do changes in each of the four functional areas impact on one performance parameter.
7c	Functional area impacts	Functional Area versus	Choose one functional area and discuss how it would impact each of

Exercise	Title	Subject	Question
		performance parameters	the performance parameters.
8a	Key Performance Parameters	KPP & KSA monitoring mechanisms	What are 5 measures of effectiveness and how are you going to monitor those metrics when evaluating M*A*S*H 4077th?
8b	Winning a 4 day pass	Gaming the System	Explain how the enterprising Zale and Klinger are going to maximize their performance metric and win the 4 day pass to Tokyo while not meeting the camp's true objective. How could you minimize the opportunity for manipulation?
8c	Ranking & Weighting the metrics	Scoring the KPPs/KSAs	Choose 5 additional metrics from your classmates' performance metrics and your own 5. Rank and weight them as if you were on a proposal evaluation committee.
8d	What can be sacrificed	Cost As Independent Variable	Reviewing your top 5 or 10 metrics, which performance metric threshold can you reduce in order to meet the 10 percent budget cut you just experienced?
9a	Assumptions	Recognizing world views.	What 3 to 5 assumptions have you made and what are their implicit and explicit implications?
9b	Change Assumption	Flexibility in design	Change one assumption 180 degrees and describe how this change impacts your system as a result. What can be adapted to meet this change?
10a	Market Survey	Market Research	Create a market research plan that represents how you would go about investigating a private sector alternative to M*A*S*H 4077th?
10b	Militarization of COTS	Adapting Technology	What are the military considerations for M*A*S*H 4077th that are not part of a straight forward market

Exercise	Title	Subject	Question
			survey?
10c	De-militarization of System	Demilitarization	What considerations should M*A*S*H 4077th consider when they retire the unit including hardware, software and weapons?
11a	Program Modernization		Identify how you would modernize and/or privatize the M*A*S*H 4077th.
11b	SWOT Analysis of Modernization	Strength, Weakness, Opportunity and Threats	Perform a SWOT analysis of the historical M*A*S*H 4077th that was portrayed in the program, the modernized unit as you imagine it, the urgent care facilities and stand alone emergency rooms that have developed over the last decade.
11c	Do we need a M*A*S*H 4077th	Revisit past Assumptions	With modern technology, improved field medics and transportation systems, do we need a M*A*S*H 4077th unit?
12a	Time Cost Performance Trade offs		What implicit or explicit trade-offs are being made between cost, quality and timeliness?
12b	Real World Trade Offs		Describe one professional trade-off you have seen personally. What trade-off occurred and what could have been done differently?
13a	Cost as a Constraint	Cost as Independent Variable (CAIV)	What are the CAIV implications for performance, functionality, schedule, staffing and logistics?
13b	Earned Value Management (EVM)	Evaluating contract performance	Discuss how the doctors evaluated the performance and effectiveness of the two examples. What could have been done differently?
13c	Performance Evaluation	Contract monitoring mechanisms	How could the Army monitor the performance of the contract to ensure the army was getting its value and not being cheated?

Exercise	Title	Subject	Question
13d	Indirect Benefits and Considerations	Other considerations	What indirect considerations or implications including advantages and disadvantages are involved in the story?

Once the exercises have been developed, the order of the exercises can be aligned with each classes syllabus (or system engineering program) as detailed in the following paragraphs.

For the SE 3100 Fundamentals of Systems Engineering Topics class, exercises are aligned with the syllabus and shown in Table 3. The selected exercises start with mission objectives with second lesson of identifying the problem. The third week looks at the boundaries, but extracting the stakeholders, which was introduced in week two. Part of boundaries is where to draw the line on which stakeholders are included and excluded. The fourth week's exercises looks at breaking the problem into functional analysis and modeling, and by creating a process flow diagram is breaking the problem into functional areas, and is needed for future exercises. The fifth week is about requirements definition, and by looking at the Key Performance Parameters and Key System Attributes, the students are going to look at requirements at a high level. It also allows my personal favorite of gaming the system. The sixth week is preliminary design and alternatives, by choosing the program modernization, we can look at the strength, weakness, opportunities and threat analysis, which is understanding the analysis of alternatives. Week seven is analysis of alternatives and decision making aligns with the CAIV and EVM management lectures because decision making is weighing the alternatives. This exercise 13 is really capstone and combines a lot of different concepts and should be considered for later in the introductory course. However in the compressed schedule, this is the most appropriate location. In week eight is test and evaluation, and that aligned with the implicit and explicit trade-offs are being made between cost, quality and timeliness. In week nine is the lifecycle considerations and the ilities of total ownership cost. At the end of the process you need to evaluate what assumption are made and their implications, so this exercise is aligned with near the end of the program as a post

laboratory experience analysis. The week 10 exercise is the process models, and course recap. The data processing exercise permits data modeling and how the system fits into the larger picture including external customers (stakeholders) data handling.

For the SI 4021 System Engineering for Product Development class the exercises are aligned with the syllabus as shown in Table 4. In Week two, the focus is problem solving with system engineering so mission objectives exercise is the natural starting point. In week three we look at requirements analysis which lends itself to the exercise 2, the stakeholders identifications and associated metrics. However part of week three is functional decomposition which lends itself to exercise 7 directly with the hardware, software, data, and people decomposition. However exercise 7, is rather complex and requires a system engineering familiarity that may not be appropriate here. In week 4, we look at models to assess system engineering which aligns with exercise 3, System Engineering deconstruction and the functional flow diagrams. In week 5 is the midterm exam, allowing the students to do the data processing (moved from final week in SE 3100 alignment). In week six, the requirements analysis of various types are addressed, and that aligns best with the KPP and KSA and the gaming the system exercise. In Week seven we address stakeholders, and business models and requirements and that aligned with the implicit and explicit trade-offs are being made between cost, quality and timeliness. In week eight we look at gap analysis which is assumptions in exercise 9. In week nine, we look at decision making and risk assessments which relates well to the CAIV exercise. In week 10 is the final exam, and I again chose the program modernization effort which addresses the SWOT and AoA processes that the students are intuitively addressing when designing a new system.

Table 3. Exercise Alignment with SE 3100

Week	**Class Topic**	**Exercise**	**Questions**
1	Course Overview Critical Thinking Problem Solving via Systems Engineering		
2	Identifying *The* Problem—Stakeholders	*Exercise 1) Mission Objectives* *System Metrics (option 1)* *Thresholds & Objectives (option 2)*	What are the Operational Requirements for the M*A*S*H 4077th?
3	Refining *The* Problem – Boundaries and Scenarios (Note: Columbus Day)	*Exercise 2) Stake holders* *Included and excluded Stakeholders* *Stakeholder concerns* *Non Military Stakeholders*	Who are the stakeholders of the M*A*S*H 4077th? What are their interests?
4	Functional Analysis and Modeling	*Exercise 3) System Engineering Deconstruction (RBD)* *Bottle Necks* *HIS risk mitigation* *Risk Mitigation,* *Risk Matrix*	Create a single page block diagram of the processes with the M*A*S*H unit as you see them.
5	Requirements Definition	*Exercise 8) KPP/KSA monitoring* *Gamming the System* *Scoring and KPPs/KSA*	What are 5 Measures of Effectiveness? How will you monitor those metrics when evaluating the M*A*S*H 4077th?
6	Preliminary Design and Alternatives Generation	*Exercise 11) Program Modernization* *SWOT Analysis of Modernization* *Do we need a Mash 4077st*	Identify how you would modernize and/or privatize the M*A*S*H 4077th.

Week	**Class Topic**	**Exercise**	**Questions**
7	Analysis of Alternatives and Decision Making	*Exercise 13) CAIV analysis* *Earned Value Management* *Performance Evalution* *Indirect benefits and consideration*	What are the CAIV implications for performance, functionality, schedule, staffing and logistics?
8	Test and Evaluation (Note: Veterans Day)	*Exercise 12) Time, Cost and Performance Trade Offs*	What implicit or explicit trade-offs are being made between cost, quality and timeliness?
9	Lifecycle Considerations The –ilities and total ownership cost (Note: Thanksgiving)	*Exercise 9) Assumptions* *Flexibility in Design*	What 3 to 5 assumptions have you made and what are their implicit and explicit implications?
10	SE Process Models - Course Recap	*Exercise 4) Data Processing* *Notifiactions of supply requests* *Data passing as system monitoring* *Data Passing to external Customers*	Identify what information is passed from each block to the next.
11	Student Presentations		
	Finals Week		

Table 4. Exercises Alignment with SI 4021

Week	Class Topic	Exercise	Questions
1	**Introduction to Systems, Systems Thinking, Systems Engineering** Historical Perspective What is Systems Engineering Functional Decomposition Systems Engineering Process Block and Flow Diagrams What is a System Systems Engineering Process Roles and Responsibilities of the Systems Engineer		
2	**Solving Problems With Systems Engineering** Fundamental Equation of Systems Engineering—The Value Function Why Projects Fail The Need for Systems Engineering Lifecycle (The Product and The Need) Concept Formulation	*Exercise 1) Mission Objectives* *System Metrics (option 1)* *Thresholds & Objectives (option 2)*	What are the Operational Requirements for the M*A*S*H 4077th?
3	**Requirements Analysis** Requirements Defining the Problem Functional Decomposition	*Exercise 2) Stake holders* *Included and excluded Stakeholders* *Stakeholder concerns* *Non Military Stakeholders*	Who are the stakeholders of the M*A*S*H 4077th? What are their interests?
		Exercise 7) Functional Decomposition *Performance Parameters*	Do a functional decomposition of the M*A*S*H 4077th including hardware, software, data and

Week	Class Topic	Exercise	Questions
		Functional Area Impacts	people.
4	**Systems Engineering Process Models** Waterfall Process Model Incremental Process Model Evolutionary Process Model Spiral Process Model Domain Process Model Vee Process Model DOD 5000. Model EIA 632 Model Integrated Product and Process Development Process Model Functional Analysis	*Exercise 3) System Engineering Deconstruction (RBD)* *Bottle Necks* *HIS risk mitigation* *Risk Mitigation,* *Risk Matrix*	Create a single page block diagram of the processes with the M*A*S*H unit as you see them.
5	<u>Mid Term Exam</u>	*Exercise 4) Data Processing* *Notifiactions of supply requests* *Data passing as system monitoring* *Data Passing to external Customers*	Identify what information is passed from each block to the next.
6	**Requirements Analysis** Role of Process Models in Requirements Analysis Role of Standards Stakeholders Conceptualization Requirements System Boundaries Types of Requirements Triad of Requirements Requirements Decomposition	*Exercise 8) KPP/KSA monitoring* *Gamming the System* *Scoring and KPPs/KSA*	Explain how the enterprising Zale and Klinger are going to maximize their performance metric and win the 4 day pass to Tokyo while not meeting the camp's true objective. How could you minimize the opportunity for manipulation?
7	**Standards, Stakeholders, Business Models, and Requirements** Systems Acquisition	*Exercise 12) Time, Cost and Performance Trade Offs*	What implicit or explicit trade-offs are being made between cost, quality and timeliness?

Week	Class Topic	Exercise	Questions
	Process		
8	**Systems Engineering Process** Gap Analysis	*Exercise 9) Assumptions* *Flexibility in Design*	What 3 to 5 assumptions have you made and what are their implicit and explicit implications?
9	**Robust Design, The Systems Engineer, Decisions, Risk, and Testing** Business Operational Models Quality Function Deployment How to Present Material (supplemental material) Introduction to Decision Making Introduction to Concept of Risk Introduction to Models	*Exercise 13) CAIV analysis* *Earned Value Management* *Performance Evaluaion* *Indirect benefits and consideration*	What are the CAIV implications for performance, functionality, schedule, staffing and logistics?
10	<u>Final Exams</u>	*Exercise 11) Program Modernization* *SWOT Analysis of Modernization* *Do we need a Mash 4077st*	Identify how you would modernize and/or privatize the M*A*S*H 4077th.

Instead of aligning the exercises in a single course, the exercises could also be leveraged across the PD-21 and SE 311 curriculums with a proposed exercise allocation by class. Although each class could integrate additional or alternative exercises, the proposed allocation ensures each exercise and associated critical learning points are covered in at least one class. The allocation of exercises to classes outside the core curriculum helps create continuity across the programs. Integrating the M*A*S*H exercises in each class and alignment with particular lectures has been left for the individual faculty member to evaluate for his/her own individual teaching styles.

In Tables 5 and 6, each class within the programs, has associated exercises that support that classes learning points and ensures that each exercise is used at least once during the program. Having multiple classes do the same base exercise, but different Phase 2 questions allows for building on a unified foundation. The revisiting of base exercises in different classes will demonstrate student growth over the course of the program.

Table 5. Exercises Alignment with PD-21 Program

PD-21 Program	**Associated Exercises**		
SE 3108 Leadership in Product Development	1b	8c	
MN 3117 Organizational Processes	2d	7b-c	
SI 4021 Systems Engineering for Product Development	1c	3d	4d
MN 3145 Marketing Management	10b		
SI 4022 Systems Architecture	7b	9b	
ME 4702 Engineering Risk Benefit Analysis	3d-e		
MN 3156 Finance & Managerial Accounting	No Current Exercises		
MN 3392 Systems & Product Management	6b	9b-c	
OS 3211 Systems Optimization	6b-c		
SE 3910 System Evolution & Technology Assessment	11b		
MN 4379 Operations Management	9b	12b	13b
SE 3302 System Suitability	2c	3b	11c
SE 4003 Systems Software Engineering	4c	11b	
SE 3303 Systems Assessment	9b	12b	13c

Table 6. Exercises Alignment to SE 311 Program

Systems engineering (311)	**Associated Exercises**		
SE 3100 Fundamentals of SE	1c	3d	8d
SE 3011 Eng Economics and Cost Estimation	2c-d	10b	
SE 3302 Systems Suitability	2c	3b	11c
SE 3250 Capability Engineering	6b	8d	
SE 3303 System Assessment	9b	12b	
SE 4150 Systems Architecture and Design	3d-e	11b	
SI 3400 Fundamentals of Engineering Project	1b	5b	12b

Systems engineering (311)	Associated Exercises		
Management			
SE 4003 Systems Software Engineering	4c	11b	
SE 4151 System Integration and Development	3c	4e	8b
SE 32101 Engineering Systems Conceptualization	2b	7b-c	
SE 3302 Engineering Systems Design	3c		
SE 3203 Systems Implementation & Operation	6c	13b	

E. STEERING LETTER GUIDANCE

The steering letter generation process guidance taken from each exercise and consolidated into Table 7. This is not intended to be all inclusive guidance, but used as a template. Some follow on or phase 2 questions can be seen in the M*A*S*H example in the appendix A and the Table 2 guide. As a steering letter is not created for any phase 2 question, only choosing an appropriate question based on the lectures and syllabus or based upon student submissions and responses in the associated phase 1 is needed. Choosing which phase 2 question to use is left to the faculty member and no additional guidance is required or provided by this thesis.

Table 7. Guidance for Building Each Exercise

Exercise	Title	Subject	Exercise Instructions
1	Mission Objective	System objectives	For the steering letter include the obvious unit, system objective and at least two primary and two secondary objectives. Try to spread the objectives identified in the steering letter among primary and secondary stakeholders and a non-person stakeholder objective.
2	Stakeholders	Stakeholders	For the steering letter include the obvious metrics of success and two secondary objectives to which the students will assume who is the primary stakeholder and secondary stakeholders.

Exercise	Title	Subject	Exercise Instructions
			Also identify a non-person stakeholder directly, which will lead in later exercises that references the hardware, software, data and people that could also be viewed as a stakeholder.
3	Systems Engineering Deconstructions	Measure System Effectiveness	For the steering letter instead of trying to outline the system for the students, look at performance metrics that are indicative of the various system components. Include the obvious unit description and allude to at least two primary numeric (quantitative) metric and two subjective metrics. Try to balance a qualitative and quantitative against both a primary and secondary stakeholders. So two primary stakeholders each have one of each and two secondary stakeholders have one of each also. Try making at least one of the metrics against a non-person entity. The goal is balance metrics to meet the larger purpose mission goal.
4	Systems Integration	Data Processing	For the steering letter include the obvious unit description and allude to at least two primary numeric (quantitative) metric and two subjective metrics. Try to balance a qualitative and quantitative against both a primary and secondary stakeholders. So two primary stakeholders each have one of each and two secondary stakeholders have one of each also. Try making at least one of the metrics against a state person entity. The goal is balance metrics to meet the larger purpose mission goal.
5	System Layout	System Processes	For the steering letter outline the basic steps that are required for the system in the letter. This is similar to the RBD

Exercise	Title	Subject	Exercise Instructions
			exercise, where you identify inputs, outputs and processes. Then break them into two or three components each and relate how they those items relate to inputs, output, or processes or support needed to process an input or prepare an output. The objective is to get students to recognize flow and the acceptance of some less than optimal design of any solution, as we can never make everybody happy. In your guidance letter, someone has to complain about something in the current design or process, where the solution may be to do nothing.
6	Linear Programming	Linear Programming	Ask the students to do a word problem on the system where a linear program will need to be written. This is indentifying two or three types of inputs and two or three outputs and two or three constraints associated with the system. Look at people and equipment or supplies in and out of the system. There should be two mechanisms for getting those items in and out, boat, airplane, truck, bus, tanker that can be used as transports. Then identify some constraints against each input and mechanism to create the model.
7	Functional Decomposition	Hardware, Software, Data, and People	For the steering letter we need to focus on the processes within the system. Identify the three or four major processes within the system and identify one or two hardware, software, data and people of each of the major processes, and then choose one or two of each of the four types from the three or four major processes. Ensure that each of the

Exercise	Title	Subject	Exercise Instructions
			three or four major processes areas has at least one of the reference, and that all four areas ideally has at two examples references in the letter. Give them examples of each different trade space between the processes and functional areas with the items chosen. Let the students fill in the rest.
8	Key Performance Parameters	Primary KSA/KPP	For the steering letter at least one of the KPPs and KSAs will be addressed directly and with a supporting trade space explicitly identified. Then identify a secondary stakeholder and discuss their goals. Try to identify and discuss a subjective but equally important objective that will be almost impossible to quantify. Try to identify some system trade space that has no direct impact on a KSA/KPP. This is trying to get students to understand there may be functional area trade space that do not actually impact the KSA/KPP, but will be defined later as part of a lower level requirement. Finally identify a non-person stakeholder and what that entities requirements may be in the letter.
9	Assumptions	Recognize world views	For the steering letter include the obvious assumption that the students will make when using their cultural reference. What if some element of the enabling system environment which was present in the system was removed, and how that would change the system. Remove an input to the system, and discuss its impact. Remove a process within the system and discuss its impact. Remove a desired outcome from the system that can no longer be met and

Exercise	Title	Subject	Exercise Instructions
			discuss its impact. Get the story teller to express some surprise or skeptism that the way some other people or stakeholder are interacting with the system. This can be a good surprise (unexpected benefit) or a bad surprise (extra costs work for other), or just different neither good nor bad. Assumptions and expectations can and will naturally change, and if you can reference the subtle changes that occur as the system evolves that would be good.
10	Market Surveys	Analysis of Alternatives	The system being analyzed is intend to fix some problem or deficiency, so just try to give some short story of what that problem was that the solution is intended to fix or the systems mission objective. Identify some deficiency within the current solution that may be a perceived impetus to making a system change and then guide them into what generally alternatives might be available. Include cost (financial or people) implications reference somewhere in the story. Where possible include some references to the hardware, software, data or people so the links to system engineering considerations are present.
11	Program Modernization	Change Processing	For the steering letter understand that the intent is really to get students to identify opportunities within the system to do it better, cheaper or faster. Part of our modernization is the network centric warfare, so discuss how internal and external users may use that data. The first step is to briefly identify what is coming into the system and leaving the

Exercise	Title	Subject	Exercise Instructions
			system and what is generally happening along the way. Then break each of the inputs, outputs, processes, into one or two items where things can be done differently but do not mention a solution, but only identify the problems or slowdowns the antiquated processes are causing. Bring the conversation to the desired outcome at the end, so students are guided through inputs, processes, and outputs modernization. Depending on the cultural reference, allude to changing not just parts within the system, but how the entire system is used and operated,
12	Trade Space	Time, Cost & Performance	For the steering letter understand that the intent is really to get students to identify trade space within the system to do it better, cheaper or faster. The trade space may be between hardware, software, data and people. The trade space may be between inputs, processes and outputs. The trade space may be between metrics, objectives and KSAs. Try to include examples of each of four areas to show examples.
13	CAIV	Trade Space with CAIV and EVM	This exercises is intended to get students to recognize and identify trade space within the system to do it 1) better, cheaper or faster, 2) hardware, software, people and data, 3) Inputs, process and outputs, 4) metrics, goals and KSA and 5) performance, function and schedule.

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V. CONCLUSION

This thesis proposes using a common cultural reference and a modified case study methodology for discovering the underlying system and system engineering elements. Instead of trying to extract the learning points from a detailed narrative of the traditional case study, we are having the students fill in the system elements that were not fully explained in the cultural reference. This process is similar to what the system engineer will face where the objective and some constraints may be known initially, but there are many unspecified critical details and unknowns when designing a new system.

The selection of the exercise topics as articulated in the 13 exercises and their associated development methodologies were designed to cover the breadth of the system engineering experience. The phase 2 or follow on questions provide flexibility for the faculty to delve deeper into various topics to address class dynamics and permit the easy modifications of the learning experience across classes and programs. The development methodologies also provide a template for creating new future exercises to the future cultural references as they become popular. Between each exercises methodology, steering letter guidance and M*A*S*H example, the faculty should be able to generate new cultural reference exercises pretty easily, because the intent of the exercises is to steer the discussions and submissions and not to be overly definitive in the students instructions.

While the exercises may be used in consecutive weeks within a single introductory course, they can also be leveraged across the systems engineering program, by have the students prepare longer or more detailed submissions for the relevant exercises. When using the same cultural reference exercises within a single class or across a program some fatigue can creep in where the students feel “here we go again.” If multiple sets of exercises using different cultural references are created, the classes can revisit the same three or four cultural references for different exercises. The potential advantage is changing references will show that the same learning points are present in many situations, but provide continuity in the approach and can still build on previous exercises with the same cultural references.

While the exercises can be used in either the short or longer answer format, an assessment of which length is best considering both the substance and level of discussion the different length responses generate when balanced against student time and learning. This will be subjective saying the 400–600 submissions generated greater diversity of ideas and discussions vice the average amount of time the students are spending generating the submissions and the discussions. Some systematic assessment of different groups using only the short answers, some only using longer answers and some mix where students who have expertise in an area as asked to give longer answers and others are asked to give shorter answers. Although not even considered, a control group of not giving comment lengths at all and seeing how well that works (or doesn't work) should be considered. The intent is not to grade on number of words, but the level of interaction and diversity of ideas presented.

While the M*A*S*H exercises are designed for the systems engineering program, applying these lessons to other areas or even additional systems engineering classes could necessitate the creation of additional exercises. Both the additional exercises and leveraging them in different programs and environments, such as short symposiums, should be investigated. The use of short power point presentations either before or after the exercises should be investigated to better integrate the M*A*S*H experience into the curriculum. Scoring or evaluating student performance and measuring the effectiveness of these exercises as part of the learning experience will be subjective but should be investigated.

These M*A*S*H exercises were created for the NPS Systems engineering program. However, the exercises could be used in other programs such as Defense Analysis, Information Systems, or Operations Research. For those programs, the creation of additional exercises to cover additional learning point exercises specially tailored to those curriculum should be created. In Appendix D, there were topics that were intentionally excluded because they were deemed too narrowly focused for the Systems Engineering Program but may be appropriate and needed for other programs.

The ability to monitor the effectiveness of these exercises remains an issue with any learning tool. How students perform on exams with and without these exercises is not

expected to see significant quantitative improvement, but the qualitative value of being exposed to the diversity of backgrounds from the fellow students should be enlightening for the students. The first analysis should be to identify whether using these M*A*S*H exercises has a positive effect on the students understanding of the System Engineering comprehension. This would require human factors analysis which is outside the scope of this thesis. This first analysis will likely would involve a review the discussion boards across multiple cohorts along with feedback from both the individual students and faculty to evaluate their effectiveness and contribution to the learning the systems engineering process in creating a unified experience across the curriculum.

A next area for future analysis would be to investigate how, where and what to look for in the submissions and discussions to identify knowledge gaps that should be revisited during subsequent lectures or revised Phase 2 questions. The resulting selection of the Phase 2 questions (pre-selected question or revised questions) can be evaluated for overall effectiveness.

The end of the class evaluation forms should include some questions targeting the effectiveness of the M*A*S*H exercises from the students and faculty. This data should specifically look at how well the students and faculty felt the exercises were in reinforcing the class' learning points. The surveys should also include a question about the effective of these exercises in creating continuity across the core curriculum classes into a coherent program. The final survey question should be a question of what worked well about the exercises and what did not. Based on this feedback, future changes to the exercises can be made. There is a small risk of M*A*S*H exercise burnout where students feel "here we go again" which should be monitored and avoided.

These M*A*S*H discussion exercises, with classmates' feedback providing the recursive feedback, will emulate for distance learning students the processes, techniques and approaches the students currently experience in a physical lab course, a customer focused project or other graduate level project.

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APPENDIX A. M*A*S*H LAB EXPERIENCE EXERCISES

Exercise 1a: Mission Objectives (System Requirements)

Your team has been asked to review the 4077th Mobile Army Surgical Hospital (M*A*S*H) system of systems. Read Radar's letter home and then answer the following question in 500 to 600 words: What are the operational requirements for the M*A*S*H 4077th? Also, comment on at least two other students' responses.

Dear Mom,

*The boat finally docked in Pusan. I am assigned to the newly organized Mobile Army Surgical Hospital 4077th. M*A*S*H is a small 25 bed hospital with 4 doctors, 12 nurses, and 20 support staff in various functions. Although the hospital has only 33 people on the official roles, there is also a Military Police group assigned for support. I am not exactly sure what our roles are supposed to be, because the only doctor we have met so far is a nice guy, who was head of surgery at a hospital. Since we have not fully assembled, that doctor was transferred to another unit. The next thing I heard, he had been transferred permanently. The next thing I heard is that a pediatrician was assigned to us as we would be doing double duty helping the locals. Then that doctor was assigned elsewhere. I have really no idea what the unit I am supporting is supposed be about, but this officer tells me what to get, and I try getting it. This officer, who is not part of our unit, just told our group to catch the truck of supplies we have been gathering as we are heading up north somewhere. I will write again when I get wherever they are sending me.*

Love, Walter

Exercise 1b: System Metrics (Measuring KPPs)

Choosing your preferred operational requirements, answer how will the operational requirements be measured? Justify your answer in 300 to 400 words. Comment on two other students' answer.

Exercise 1c: Thresholds and Objectives

Identify a threshold and objective for two your Operational Requirements, and how you determined those values? Justify your answer in 300 to 400 words. Comment on two other students' answers.

For the professor: Exercise 1 Methodology

Within the DOD environment, the analysis of alternatives (AoA) and the Joint Capabilities Integration and Development Systems (JCIDS) will result in a Material Solution Analysis (MSA) which includes system requirements or needs solution that the program is intended to address. The above Exercises 1a-c replicate this exercise. For Exercise 1b, the MSA will include key performance parameters that the solution is intended to meet. For Exercise 1c, the final KPP thresholds and objectives are a result of both what is achievable and desirable and a result of a negotiation process among stakeholders. Having the students explain the chosen thresholds and objectives will give insight into the students' thinking. As the students come from various backgrounds, the multitude of answers will be representative of various stakeholders.

For the professor: Question Generation Process

Ask the students to identifying the underlying system objectives.

For the steering letter include the obvious unit, system objective and at least two primary and two secondary objectives. Try to spread the objectives identified in the steering letter among primary and secondary stakeholders and a non-person stakeholder objective.

Lesson 2a: Stakeholders

Read Radar's letter home and answer the following question in 500 to 600 words: Who are the stakeholders of the M*A*S*H 4077th? What are their interests? Also, comment on at least two other students' responses.

Dear Mom,

*As I wrote in my last letter, I told you about my new CO, Lt Colonel Henry Blake, and how I am trying to help him set up the M*A*S*H 4077th. Well, Mom, the Army has allocated all the staff and equipment, but it is spread out across half of Korea. Most of the staff has arrived and are working on the wounded, but some are held up in Seoul. A Captain Burns somehow got to Tokyo and is stuck there until they can find a flight over. I had to send two guys down to Ulson to pick up our generator, and it took them three days. It is only 150 miles each way with the detours. We had a liaison with the Koreans Military named Kai-ue, at least that is how it sounds. He is a good enough guy. He was from Wonson, which is north of here a ways, but his entire family is in a refugee camp near what sounds like Eonson. The funny thing is Wonson is on the East Coast of the Korea while Eoson is on the West Coast of Korea.*

Colonel Blake is constantly on the phone trying to get people assigned to the unit. The staff is assigned, but they have not gotten their orders. Blake is constantly asking for forms to get them or supplies released to the unit. It seems like each branch has its own forms. The Navy wants one form to get material release from their base over near Inchun (that is where Mcarthur landed), and a different form from the Army warehouse just two blocks away from the Navy base. Even though we have flights from Soeul and Tokyo from Pusan, we have to call different places to get seats on the flights depending on its destination.

About a half mile down the road there is a little orphanage. It used to be owned by some rich land owner, but he and his family disappeared during WWII and at some point the orphanage moved in. They are great little kids, and I love visiting them. It is amazing that just the smallest pieces of chocolate make the children happy. I hear a helicopter coming from the south. I am hoping it is some more nurses. We only have 9 of the 22 we are supposed to. Wait, multiple helicopters, that means wounded.

Love, Walter

Exercise 2b: Included or Excluded Stakeholders (Who are the customers?)

Chose a stakeholder from another student's list that should have been included in your list and why? Identify a stakeholder from another student's list that should not be considered a stakeholder and why? Justify your answer in 300 to 400 words. Comment on two other students' answers.

Exercise 2c: Stakeholders concerns (KPP/KSA allocations by stakeholder)

Choose a stakeholder on your list and identify which KPP/KSA from Exercise 1 this stakeholder should be concerned with and why? Justify your answer in 300 to 400 words. Comment on two other students' answers.

Exercise 2d: Non-military Stakeholders KSA (New stakeholder KSAs)

Choose two stakeholders with at least one of which is not military, from your list or that of another student and identify what his/her M*A*S*H 4077th requirements and associated metric that should be. Justify your answer in 300 to 400 words. Comment on two other students' answers.

For the professor: Exercise 2 Methodology

Identifying stakeholders is an important exercise for any system development. These stakeholders may require revisiting the KPPs/KSAs for the system.

For Exercise 1b: Including a stakeholder who was overlooked is compelling the students to acknowledge that there is no product or solution that is perfect. Excluding a stakeholder is an acknowledgement that no material solution is going to be all things to all people. Trying to address everybody's need will lead to impossible requirements and unacceptable costs.

For Exercise 2c: Stakeholders' concerns should be addressed in the KPPs/KSAs. If they are not, are they really requirements or really stakeholders?

For Exercise 2d: It is occasionally necessary to revisit the KPPs/KSAs after the program's initiation to address new requirements. Exercise 2d is trying to get students to acknowledge constituencies outside of the military, as in trying to understand that any material solution is part of a larger system. Not all stakeholders will have KPP and KSA that address their needs, and recognizing that is important.

For the professor: Question Generation Process

Ask the students to identifying different stakeholders involved in the system.

For the steering letter include the obvious metrics of success and two secondary objectives to which the students will assume who is the primary stakeholder and secondary stakeholders. Also identify a non-person stakeholder directly, which will lead

in later exercises that references the hardware, software, data and people that could also be viewed as a stakeholder.

Exercise 3a: Systems Engineering Deconstruction (Reliability Block Diagram)

Read Radar’s letter home, create a single page block diagram of the processes within the M*A*S*H unit as you see them. Then upload the diagram as a PDF and explain your diagram and logic in 500 to 600 words. Comment on at least two other students’ responses. The PDF may be generated from PowerPoint, Excel or any other tool you want, but the uploaded documented must be viewable by all your classmates.

Dear Mom,

We were interviewed by a journalist a few weeks ago. They sent us a reel to watch on the movie projector. What gets me is I spent three hours with that Journalist talking about all the processes that go on here at camp from the step by step of triage and medical procedures, and all the stuff that we do, so the nurses and doctors can do what they do. I spent a lot of time on the way things are supposed to happen the Army way from ordering forms and receiving and supplies, and then on how we actually do it, by trading with other units, the Greeks and the local businessmen. Hawkeye calls it the black market. Honestly, I know I am trading for some of our own stuff that was traded to them, but it is the only way we have to get things done.

The new Colonel Potter is an old Army guy, who was in the Calvary in WWI and served in both Europe and Asia during World War II as a doctor and now Korea. I know he finds this whole organization “damn irregular.” I think he is trying to change the culture here without changing the culture. He wants to change everything, but nothing at the same time. He claims to have seen it all before. Max Klinger, the corporal who goes in around in dresses, visits the new colonel every day. The Colonel sends him away every day, it is a running joke. I was helping register some patients that came in by jeep the other day and Max ran by the Colonel with some fresh bandages for the patients without being asked. As Col. Potter was inspecting the soldier, I heard the Colonel say “If he was not so good when he is actually needed, I might actually consider giving him his ticket home.” I think he meant it as a compliment, but he never told Klinger it directly.

Love, Walter

Exercise 3b: Single Points of Failure (Bottlenecks)

Review your process flow diagram. Identify any single points of failure and what steps can be done to mitigate this failure mode or bottleneck. What is the impact of the failure? Justify your answer in 300 to 400 words. Comment on two other students’ answers.

Exercise 3c: Human Factors Risks (HSI Risk Mitigation)

Indicate what steps you could take if the flu hits the M*A*S*H camp and half of your staff becomes sick. What is the impact of this failure mode? Justify your answer in 300 to 400 words. Comment on two other students' answers.

Exercise 3d: Risk Mitigation (Redundancy contingencies)

Review your process flow diagram. Identify what you think is the riskiest (likelihood and consequence impact) task. What could you do to mitigate it? Justify your answer in 300 to 400 words. Comment on two other students' answers.

Exercise 3e: Risk Matrix (Quantifying the Risks)

Choose your top five risks and place them on a Risk Matrix. In 300-400 words explain why each of the five points are where you placed them. Comment on two other students' submissions.

For the professor: Exercise 3 Methodology

This exercise is not so much what is right and wrong in any given processes but getting the students to try breaking it down as they see fit.

Exercise 3b is intended to get the student to look for structural or design weaknesses in the camp's processes and identify mitigation or design redundancies or alternatives (less optimized solutions).

Exercise 3c is trying to get the students to recognize the importance of human factors in this M*A*S*H unit or any system.

Exercise 3d is intended to not just identify single points of failures, but to rate the impacts of the failures.

The end learning objective of this exercise is to design a system with sufficient redundancy that if any one element or one system goes down, we do not lose the ability to continue at some reduced level. Even as students add redundancy to improve availability and performance, they simultaneously add complexity and costs into the systems.

For the professor: Question Generation Process

Ask the students to identifying how they intend to measure system effectiveness.

For the steering letter instead of trying to outline the system for the students, look at performance metrics that are indicative of the system components. Include the obvious unit description and allude to at least two primary numeric (quantitative) metric and two subjective metrics. Try to balance a qualitative and quantitative against both a primary and secondary stakeholders. So two primary stakeholders each have one of each and two secondary stakeholders have one of each also. Try making at least one of the metrics

against a non-person entity. The goal is balance metrics to meet the larger purpose mission goal.

Exercise 4a: Systems Integration (Data Processing)

Read Radar's letter home. Using your single page block diagram of the processes from Exercise 3, or a revised one, identify what information is passed from each block to the next. Then upload the diagram as a PDF and explain your diagram and logic in 500 to 600 words. Comment on at least two other students' responses.

Dear Mom,

Sometimes I feel like I am juggling more balls than I can count Mom. To matters worse, each ball has its own paperwork. To get food, it takes paperwork. To get medical supplies, it takes paperwork. To get replacement car parts, it takes paperwork. Each set of paperwork asks for a justification. If I want auto parts, they want to know how many miles the cars have been driven. If I want penicillin, they want to know how many patients we had that week. If I want toilet paper, they want to know how many people we have in the camp. The real issue is trying to get the counts as needed. The nurses and doctors are really good about entering the medical conditions of the patients, what they give each patient and when. Yet when it comes to recording how many whole blood units used or how much of a given medicine they used, the staff just grabs what they need. Then the staff complains when they run out. Max and Nurse Chapel are real good about going through the store room and counting, but we are always counting what is left. Zale tells me what he wants auto parts wise for the motor pool but not why. I came up with an off the cuff method. Each item has a count, if we need more x-ray film, I just tell them we have taken 100 images since the last request. Sparky, told me to never make it nice round numbers so I always say 97 images or 102 Rolls of paper used. Max helped me create a cheat sheet where we record what we need for each time, and a count of where we were last on the last order form. It seems to make everyone happy, but I am not sure anyone is really even looking at the used numbers anyway.

Captain Hawkeye says the only thing he cares about is "the number of injured who come in with a pulse is the same number we send on." All I can think about is that Mike Johnson from over in Mt. Pleasant went home. I think what we all want is for this war to be over so we can all just come home.

Love, Walter

Exercise 4b: Notification of Supply Requests (Event Triggers within the System)

Review the data between each block. Which data items could be leveraged to let Radar know how many supplies to order and when? Justify your answer in 300 to 400 words. Then comment on two other students' answers.

Exercise 4c: Data Passing as System Monitoring (Performance Monitoring)

Review the data required to and from each block. What metrics can be generated to monitor the camp's performance? Justify your answer in 300 to 400 words. Comment on two other students' answers.

Exercise 4d: Data Passing to External Customers (External Interfaces)

Review the data required to and from each block. Which data should be transmitted to external customers (outside the M*A*S*H unit)? When? Why? How? Justify your answer in 300 to 400 words. Comment on two other students' answers.

Exercise 4e: Modern Logistics Managements (Digitalization of the Process)

Review the data required to and from each block. Describe the processes of how you would digitize the processes. How would it improve the processes? Justify your answer in 300 to 400 words. Comment on two other students' answers.

For the professor: Exercise 4 Methodology

Data validation and feedback loops are critical for any system to ensure the system is meeting the requirements and that data flow is part of the verification process. Historically, data processing for patient treatment was separate from logistics support, and separate from program management (process evaluation). However, the data processing can be monitored as part of a condition based management process, and the same data can be leveraged for multiple uses. By doing multiple questions on the same data, students can understand how to leverage data for other uses.

Many of our digital systems today cannot only use internal digital sensors, as part of built in testing (BIT), to monitor itself and its performance, but it can share that data if so designated. The result is that the user or engineer has to know what data is useful or relevant for a particular purpose. We can literally overwhelm a particular user with data, but we must filter which data is appropriate for whom, which is not an easy task.

For the professor: Question Generation Process

Ask the students to identifying the basic outline of the process.

For the steering letter understand that the intent is really to get students to break the system down into smaller and smaller parts. The first step is to briefly identify what is

coming into the system and leaving the system and what is generally happening along the way. Then break each of the inputs, outputs, processes, into two or three components and identify those indirectly via the items needed during each of the six to nine components you outlined. If you have nine items identified, you can use the clerk, trainer or other coordinator not to just list them, but identify what each is used for, how that item or process needs to be prepared and how it can be tracked. You are not listed the nine items, but listing a few, identifying how some are used and how some need to be prepared. Bring the conversation to the desired outcome at the end, so students are guided through inputs, processes, and outputs.

Exercise 5a: Camp Layout (System Space Allocation)

Read Radar's letter home. Create a single page layout for the M*A*S*H. Upload the diagram as a PDF and explain your diagram and logic in 500 to 600 words. Comment on at least two other students' responses. The PDF can be generated from PowerPoint, Excel or any other tool you want, but the uploaded document must be viewable by all your classmates.

Dear Mom,

Privacy is both a blessing and a curse. In a small camp such as the 4077th, it is hard to keep secrets from each other. Although we cover the area of three football fields, (one for the helicopter landing area, one football field where we all live and work, and one for the motor pool and other support areas), it is a rather constrained existence. Except when going on supply runs or to go trading, most of us never leave the camp. Even Rosie's the local bar that was set up right next to camp, we live our lives in close proximity. Where we get privacy is non existence, but it also lets us keep an eye on each other so we can look after each other because we are one family.

*Even though the camp is really small, Private Igor is complaining that the camp warehouse is too far from the kitchen. Zale complains he spends a quarter of his time, running back and forth from the motor pool to get parts. Captain Pierce insists that the store room be adjacent to the operating rooms. Major Burns said we should just build three separate store rooms one for each group. So we ordered the extra tents, however once they arrived, I traded them to the M*A*S*H 4022nd for some replacement refrigerators to keep both the critical medicines and the fresh vegetables fresh. Zale came asking for his auto parts warehouse, and I told them they had not arrived. What he does not know will not hurt him.*

We are really living and working in a very small corner of Korea, going between the surgery and recovery areas, the store room, the kitchens and the showers and latrines. When the wounded are not coming in this place really is a beautiful country, even if we rarely get to explore it.

Love, Walter

Exercise 5b: SWOT Analysis of the Layout

Review the camp layouts of your classmates. What are some of the Strengths, Weaknesses, Opportunities and Threats (SWOT) of their camp layout? Using at least three of your classmates' layouts, describe two elements for each category. These eight elements should be 30 to 50 words each for a total of 200 to 400 words per response. Comment on two other students' answers.

For the professor: Exercise 5 Methodology

Camp or system design is not just the identification and allocation of the functional steps of the M*A*S*H 4077th. It is also the mechanical structure (layout) of the camp. The next step is the analysis of the results using the SWOT analysis technique. Designing the layout, flow of the camp and patients passing through the camp is similar to designing a system for data processing for a new combat system or mission space allocation in a new ship design.

For the professor: Question Generation Process

Ask the students to identifying the draw a basic layout of the system and the whys of their diagrams.

For the steering letter outline the basic steps that are required for the system in the letter. This is similar to the RBD exercise, where you identify inputs, outputs and processes. Then break them into two or three components each and relate how they those items relate to inputs, output, or processes or support needed to process an input or prepare an output. The objective is to get students to recognize flow and the acceptance of some less than optimal design of any solution, as we can never make everybody happy. In your guidance letter, someone has to complain about something in the current design or process, where the solution may be to do nothing.

Exercise 6a: How Many Trucks

Read Radar's letter home. Solve the linear equation for how many trucks and ambulances should be bringing supplies to the M*A*S*H 4077th. Write 200-300 words explaining your process. Comment on at least two other students' responses.

Dear Mom,

Everything here takes a form. If we want fresh vegetables, it takes a form. If we need replacement staff, it takes a form. Heck, they even have a form for the dead to be transported out of here. Last week, Zale took a truck and an ambulance down to ICOR to pick up supplies, since they did not have enough trucks to send up. The ambulance has air conditioning that we need to transport the medicines and the like. Although we also transport fresh vegetables and ice cream if they have it.

Most weeks, we get two trucks and an ambulance sent up. Some weeks they send us six trucks and none of them are even half full. They say it is because if a trucks breaks down, they can off load the supplies onto one of the good trucks and we will still get everything. Sometimes, I think they are sending the trucks so that each soldier is being used (something about a utilization rate.) Would it be the end of the world if they let some guys have a day off now and then?

Love, Walter

Each truck can carry 600 cubic feet of supplies.
Each food unit for a soldier for the week takes 3 cubic feet. There are 58 camp members.
The unit treats an average of 70 wounded a week, and each one stays for on average of three days.
Each fresh vegetable for the week per person is 1 cubic foot, but it needs to be air conditioned.
The medicines and blood for each patient is 2.5 cubic feet and needs to be air conditioned.
Each fuel truck carries 500 gallons, and the staff and wounded take one galloon each per week.
If a truck is carrying fuel, it will not carry anything else.
If there is extra room in the ambulance, it can be filled with dry goods.
Each ambulance has 250 cubic feet of space.
Consumables like toilet paper, bandages and clothing varies by patient and type of injury, but average 1.5 cubic feet of consumables per person (128 people) each week.
The replacement generator takes up 300 cubic feet.
The replacement water pump will take up 425 cubic feet.
The replacement water piping takes up 72 cubic feet.
The mail bags take up between 10 and 20 cubic feet per week.

How many trucks and ambulances do you need?

Exercise 6b: Additional Constraints.

The simple linear program gives a specific solution for the number of trucks needed per week. What adjustments would you make if you were at ICOR and were responsible for getting the equipment to the M*A*S*H 4077th? Justify your answer in 300 to 400 words. Comment on two other students' answers.

Exercise 6c: Sensitivity analysis?

a) What if each person takes 2 square feet per week for personal products?
b) If you allow dry food on the fuel truck, what changes need to be made to your solution?
c) How does increasing patients from 70 per week to 140 change the metric?
d) What changes by decreasing patient stays from 3 days to 2 days?
e) What happens if on average 1 vehicle a week becomes disabled?
f) In the winter, it is cold enough so no ambulances are needed. How does that impact your solution?

What adjustments would you make to address each of the above items? Write 300-400 words to discuss the answers.

For the Professor: Exercise 6 Methodology

This exercise is an example of a simple linear program, but when you allow material to be shared between trucks and ambulances you should be able to save space and vehicles. The discussion concerns variables they can do outside of specified rules to reduce the number of trucks. If you do not let dry goods on the ambulances what does that do? During the winter will they still need ambulances to transport temperature sensitive supplies?

The excel file has a sample solution. There are several assumptions in the bottom of the excel sheet that I have considered in the sensitivity analysis. Students should set it up with the appropriate constraints.

For the professor: Question Generation Process

Ask the students to do a word problem on the system where a linear program will need to be written. This is identifying two or three types of inputs and two or three outputs and two or three constraints associated with the system. Look at people and equipment or supplies in and out of the system. There should be two mechanisms for getting those items in and out, boat, airplane, truck, bus, tanker that can be used as

transports. Then identify some constraints against each input and mechanism to create the model.

Exercise 7a: Functional Decomposition (Hardware, Software, Data and People)

Read Radar's letter home and answer the following exercises in 500 to 600 words: Do a functional decomposition of the M*A*S*H 4077th (hardware, software, data and people). Comment on at least two other students' responses.

Dear Mom,

The war has been heating up along with the warmer weather. Last week our supply trucks got hit. Two were destroyed. The remaining trucks returned back to Ulson, so we did not get our regular delivery. In addition, the fighting has resulted in more casualties coming while we try to keep two weeks of supplies on hand. Without the delivery and increased wounded, we have run pretty much out of everything. While our physical stuff, the tents and equipment are here, they do not do us much good without the supplies to go along with them. In addition to losing the trucks last week, our reports and patient information that we send south for supplies got destroyed. Instead of sending us the double order of supplies to make up for the lost delivery, they sent us the default low casualty supply quantity. The doctors and nurses know what to do, but it is aggravating that it is always the company clerk's fault that things are not going smoothly. They act as if I control the processes that go on in and around this place, when I am only following the 438 page guidebook. I actually just make it up as I go along following past experience and common sense.

Major Burns wanted Colonel Blake to institute morning exercise for all staff and was insisting that it was in our regulations. Blake was trying to push him off as it was not needed. When Burns wanted to show Blake the regulation, I removed the entire section from the manual, and instead of pointing to the missing section, I just pointed to the section stating when in doubt use the general unit level army instructions. Blake used that as justification to not require all staff to do morning exercises. Major Burns stormed out. Blake just told me to put the manual back together for the next time because I think he realized I had removed the section, but he was also relieved to have Major Burns out of his hair. Although he did mention that he was still expecting Klinger's daily visit.

Love, Walter

Exercise 7b: Performance Parameters (Cost, Schedule and Effectiveness)

Discuss how changes in each of the four functional areas impact on one performance parameter (cost, schedule or effectiveness). Justify your answer in 300 to 400 words. Comment on two other students' answers.

Exercise 7c: Functional Area Impacts

Choose one functional area (hardware, software, data or people) and discuss how it would impact each of the performance parameters (cost, schedule and effectiveness). Justify your answer in 300 to 400 words. Comment on two other students' answers.

For the Professor: Exercise 7 Methodology

Functional decomposition (process flow decomposition) can have implications on cost, schedule and performance. Focusing on requirements and functional allocation too early in a system development process can lead to sub-optimal solutions due to architecture, technology and process decisions artificially binding the solution. Exercises 7b and 7c are either vertical (one functional area) or horizontal performance (one criterion) and can be allocated to students to review each area or let students choose the vertical or horizontal performance area to consider. Providing both a 7b and a 7c exercise will enable the students to connect the interdependencies between functions and performance.

For the professor: Question Generation Process

Ask the students to identifying the underlying Hardware, Software, Data and People of the system.

For the steering letter we need to focus on the processes within the system. Identify the three or four major processes within the system and indentify one or two hardware, software, data and people of each of the major processes, and then choose one or two of each of the four types from the three or four major processes. Ensure that each of the three or four major processes areas has at least one of the reference, and that all four areas ideally has at two examples references in the letter. Give them examples of each different trade space between the processes and functional areas with the items chosen. Let the students fill in the rest.

Exercise 8a: Key Performance Parameters (KPP & KSA monitoring mechanisms)

Read Radar's letter home and answer the following question in 500 to 600 words. What are 5 Measures of Effectiveness? How will you monitor those metrics when evaluating the M*A*S*H 4077th? Comment on two other students' responses.

Dear Mom,

Last month, Major Burns and Lt were complaining about the powered eggs and powdered milk over at the mess tent. I talked to Cho, the local Korean businessman, who helps out. This time, he wanted some copper wire to electrify some area homes. I ordered 500 yds. of copper wire and traded it to Cho. He is now delivering eggs and vegetable to the mess nearly every day. None of the vegetables are like we grow back home. Yet fresh is still better than the rehydrated food that is our Army staples. Fresh milk is still hard to come by, but I got some sent up with the whole blood and medicines last week. It is amazing how much effort we go through to get fresh vegetables when you just head over to Market Basket. The nurses were real nice to me last week when the vegetables starting showing up. Then last week this Lt from Seoul showed up looking for why we needed the copper wire or excessive auto parts that Sergeant Zale had ordered. I am not sure what it was all about but he left camp right after lunch last Wednesday with Captains Hawkeye and Trapper.

*The general drove up on Monday to give Col. Blake and the M*A*S*H 4077th an award for having the highest survival rate last month. Hawkeye said that he could keep his unit citation. The only citation he wanted was for parking in front of his office back home. The general was upset with the unit's general lack of military precision, and he made a list of all the problems he saw in the camp that he was going to address with Henry. Then we got three buses of casualties. Col Blake was yelling at his driver to move his car, and the General was really pissed that Henry was yelling at his subordinate as I carried a soldier over to surgery. When things stopped hopping after dusk, the driver and the General were gone. Henry talked to him the next day and everything seemed OK.*

I met this guy, Mike Johnson, from over in Mt. Peasant, Iowa. He had been hit in the arm above the left elbow. The doctors amputated below the elbow. I felt really bad for him, and I spent some time with him. I spoke to him about going back to farming. He actually cheered me up because he said he would join his uncle's accounting firm. He was righted handed so it was OK, and he could resume his studies. I went to cheer him up, and he actually cheered me up. Major Houlihan said I am glad they only look at the survival rate and not the percentage of soldiers who leave with all four limbs.

I have been writing this letter as I sit by the water pump. The water pump motor died, so Zale and Klinger actually worked together to rig one of the jeeps into the water pump so we can get water for the camp. The belt

keeps slipping, so every enlisted person has to do a 2 hours shift every other day just sitting here to push the belt back into place. If it starts to slip off, you just push it back into the center because if it slips off entirely it takes four of us to get it back in place. The replacement pump has been on order for three weeks now and, as my shift is ending, I think I am going to go and try and get a replacement pump.

Love, Walter

Exercise 8b: Winning a Four Pass (Gaming the System)

Choose one metric and monitoring mechanism from another student's lists. Explain how the enterprising Zale and Klinger are going to maximize the selected metric and win the 4 day pass to Tokyo while not meeting the camp's true objective. How could you minimize the opportunity for manipulation? Justify your answer in 300 to 400 words. Comment on two other students' answers.

Exercise 8c: Ranking & Weighting the Metrics, (Scoring KPPs/KSAs)

Choose five additional metrics from your classmates' performance metrics along with five of your own. Rank and weight them as if you were on a proposal evaluation committee. In 300 to 400 words explain how you prioritized and weighted each performance metric. Comment on two other students' answers.

Exercise 8d: What Can be Sacrificed? (Cost As Independent Variable)

Review your top 5 or 10 metrics. Which performance metric threshold can you reduce in order to meet the 10 percent budget cut you just experienced? Justify your answer in 300 to 400 words. Comment on two other students' answers.

For the professor: Exercise 8 Methodology

Exercise 8 is about identifying appropriate metrics (KSA) and mechanisms to monitor the metrics. For each metric, there can be an adverse side effect to monitoring that will inevitably be gamed or have unintended side effects. Not all requirements are equal to mission success in the short or long terms and ranking them is important. Prioritizing requirements is important, but sometimes lower requirements cannot be sacrificed while higher priorities have more flexibility (trade space) in impact.

Although exercise 8 is intended as a prototype test and evaluation mechanism, it could also be used as part of scoping out the system design process

For the professor: Question Generation Process

Ask the students to identifying the primary KSA/KPPs for the system.

For the steering letter at least one of the KPPs and KSAs will be addressed directly and with a supporting trade space explicitly identified. Then identify a secondary stakeholder and discuss their goals. Try to identify and discuss a subjective but equally important objective that will be almost impossible to quantify. Try to identify some system trade space that has no direct impact on a KSA/KPP. This is trying to get students to understand there may be functional area trade space that do not actually impact the KSA/KPP, but will be defined later as part of a lower level requirement. Finally, identify a non person stakeholder and what that entities requirements may be in the letter.

Exercise 9a: Assumptions (Recognizing Stakeholder World Views)

Throughout this Systems Engineering program you have deconstructed the M*A*S*H 4077th and identified the system of systems that make up the M*A*S*H unit. Read Radar's letter home. State in 500 to 600 words what 3 to 5 assumptions have you made during these exercises. What are the implicit and explicit implications of those assumptions? Comment on at least two other students' responses.

Dear Mom,

Having worked with Kai-ue (the Korean liaison) for the past few years, I have come to realize in spite of our different appearances, the Koreans, they are really just like us. However, during a supply run last week, we were over towards the Navy base on near Ulhan, and this family was huddled in a small shack we ducked into to take cover from an artillery fire. Kai-ue started arguing with the family and when he left, all he said was that they were supposed to have evacuated this area. He was trying to get them to go to the refugee camp where they would be safer. He said they would rather die than move off the family farm. They valued the land more than life. I just do not get them sometimes.

Major Houlihan was complaining that all we get is orange juice, so we traded some fresh vegetables last week to the Greeks and got some apple and cranberry juice. Then Major Burns was upset that we were trying to poison him by putting the cranberry juice next to the orange juice where someone might mix them up. I thought people could tell the difference. Sometimes you can never take anything for granted. There is no pleasing some people.

I will probably be home before this letter arrives, as Colonel Potter has given me a hardship discharge. I am happy to be coming home but wish it were for a different reason. I thought that Max would be unable to keep things together after I left, but he got the replacement generator. So we are no longer on the small backup generator.

I did not know what I was expecting when I went to boot camp or when I got to Korea. I am not sure what to expect when I get home. I am not the same person who left for boot camp, nor the soldier who then left for Korea, or now as I leave to come home. You can share a camp with a great bunch of people for 18 months and still not really know them. You can think you know exactly how to get things done, but it is almost a certainty that it will not be the same as last time or the next time. Colonel Potter said, "The only certainty is that there are more uncertainties to come." I have my orders home, and I look forward to seeing you soon.

Love, Walter

Exercise 9b: Change Assumptions (Flexibility in Design)

Change one assumption 180 degrees. Describe how this change impacts your system as a result. What can be adapted to meet this change? Justify your answer in 300 to 400 words. Comment on two other students' answers.

For the professor: Exercise 9 Methodology

Assumptions are made every day about the power availability, security situation, staff training levels, logistics availability, and many other things. This is not a black swan identification effort, but an example in the ability to adapt to changing situations.

The most critical system failures are frequently user involvement related and are not technical challenges. The system may be truly extraordinary, but if the systems cannot be maintain, personnel trained for operations, and/or maintenance, space constraints, part and tool availability, or accessibility within current support structure, the system may not be suitable. A frequent problem is that system architecture's drive the solution and not a balance between technology, processes and people driving the solution.

For the professor: Question Generation Process

Ask the students to identifying the underlying system assumptions.

For the steering letter include the obvious assumption that the students will make when using their cultural reference. What if some element of the enabling system environment which was present in the system was removed, and how that would change the system. Remove an input to the system, and discuss its impact. Remove a process within the system and discuss its impact. Remove a desired outcome from the system that can no longer be met and discuss its impact. Get the story teller to express some surprise or skeptism that the way some other people or stakeholder are interacting with the system. This can be a good surprise (unexpected benefit) or a bad surprise (extra costs work for other), or just different neither good nor bad. Assumptions and expectations can and will naturally change, and if you can reference the subtle changes that occur as the system evolves that would be good.

Exercise 10a: Market Surveys (Market Research)

Read Radar's letter home. Create a single page market research plan that represents how you would go about investigating a private sector solution as a replacement for the M*A*S*H 4077th. Upload any diagrams as a PDF and explain your diagram and logic in 500 to 600 words. Those with graphical representations descriptions can be shortened accordingly. The graphical representation can be generated from PowerPoint, Excel or any other tool you want, but the uploaded must be viewable by all your classmates. Comment on two other students' submissions.

Dear Mom,

If something can go wrong it will and at the worst possible time. Leave it to the Army to screw up whatever they are trying to do. Last week, we ordered underwear for the soldiers were shipping out. When the wounded come in, we get them out of the dirty, bloody and otherwise disease carrying clothing, and give them medical scrubs to wear in recovery. We incinerate the old clothes for sanitary purposes. Well, last week they sent us 200 pairs of lacy women's underwear. It was not practical stuff. Even the nurses said they would not wear that stuff, although a few of them took a few pairs. I ended up trading them on the black market for some fresh vegetables, some of the local liquor and some of the military currency. The last two are useful for future needs. About a week later, Sparky called about getting those women's clothes back as they were worth about $1 a piece. Imagine that much for a pair of underpants. When I told him what we did and that we still needed fresh underwear, he said we got robbed and that we should have doubled what we asked for them.

Sergeant Zale was complaining the other day that he could run this camp much more efficiently and cheaply if he were in charge. He said he could take the money the Army spends to run the camp, do it easily for 20% less and pocket the difference. Everyone always thinks they have a better way, but there is a lot of stuff that he and even I do not see that help this place runs. If he was asked to replicate it, we would go broke pretty quickly.

Love, Walter

Exercise 10b: Militarization of COTS (Adapting Technology)

Performing the emergency room tasks of the M*A*S*H 4077th is a pretty straight forward task. What are the military considerations for the M*A*S*H 4077th that are not part of a straight forward market survey? What are some of those considerations that are likely to complicate the transition to a commercial provider? Justify your answer in 300 to 400 words and comment on two other students' answers.

Exercise 10c: Demilitarization of Systems

What considerations should the M*A*S*H 4077th consider when they retire the unit including hardware, software, and weapons? Justify your answer in 300 to 400 words. Comment on two other students' answers.

For the professor: Exercise 10 Methodology

Market research is surveying alternatives for a material solution required for a specific mission requirement. In this case, it is replacing the M*A*S*H 4077th with a civilian run and managed alternative. Market research is frequently associated with investigating business opportunities where the company can make money. For this exercise, students are asked to outline how they would conduct a market research. The second part is intended to ensure the students consider not just the financial and performance metrics in selecting a vender but also how to incorporate that non-military (COTS) product into the military's enterprise. The final Phase 2 option is having students identify end of life considerations for the system.

For the professor: Question Generation Process

Ask the students to identifying the how and why as a market survey it is really an analysis of alternatives.

The system being analyzed is intend to fix some problem or deficiency, so just try to give some short story of what that problem was that the solution is intended to fix or the systems mission objective. Identify some deficiency within the current solution that may be a perceived impetus to making a system change and then guide them into what generally alternatives might be available. Include cost (financial or people) implications reference somewhere in the story. Where possible include some references to the hardware, software, data or people so the links to system engineering considerations are present.

Exercise 11a: Program Modernization

Read Radar's letter home. Answer the following question in 500 to 600 words: How would you modernize and/or privatize the M*A*S*H 4077th? Consider the stand alone emergency rooms and urgent care facilities that are being created nationally. Comment on at least two other students' responses.

Dear Mom,

Sometimes I feel like I am juggling more balls than I can count. To make matters worse, each ball has its own paperwork. To get food, it is paperwork, to get medical supplies it is paperwork, to get replacement car parts, it is paperwork. Each set of paperwork asks for a justification. If I want auto parts, they want to know how many miles the cars have driven. If I want penicillin, they want to know how many patients we had that week. If I want toilet paper, they want to know how many people we have in the camp. The real issue is trying to get the counts as needed. The nurses and doctors are really good about entering the medical conditions of the patients, what they give each patient and when. But when it comes to recording how many whole blood units used, or how much of a given medicine they used, the staff just grabs what they need and then complain when they run out. Max and Nurse Chapel are really good about going through the store room and counting, but we are always counting what is left. Zale tells me what auto parts he wants for the motor pool but not why. I came up with an off the cuff method. Each item has a count, and if we need more x-ray film, I just tell them we have taken 100 images since the last request. Sparky, told me to never make it nice round numbers so I always say 97 images or 102 rolls of paper used. Max helped me create a cheat sheet where we record what we need for each time and a count of where we were on the last order form. It seems to make everyone happy, but I am not sure anyone is really even looking at the used numbers anyway.

Love, Walter

Exercise 11b: SWOT of Modernization Plan (Strength, Weakness, Opportunity and Threats)

Perform a SWOT analysis on the historical M*A*S*H 4077th that was portrayed in the program: the modernized unit as you imagined it, the urgent care facilities and the hospital affiliated emergency rooms that have developed over the last decade. Your answer should include a PDF of a table with the four quadrants for each of the three options. The total word count should be between 300 to 400 words. Comment on two other students' answers.

Exercise 11c: Do We Need a M*A*S*H 4077th? (Revisit Past Assumptions)

With modern technology, improved field medics and transportation systems, do we need a M*A*S*H 4077th unit? Justify your answer in 300 to 400 words. Comment on two other students' answers.

For the professor: Exercise 11 Methodology

This exercise was focused on changing the organization, which would lead the students to implement the changes. Yet to change, one needs a vision of where the organization is going and how it could be. Exercise 11b use the strength, weakness, opportunity and threat constraint to image how it was (baseline), how it could be and an alternative view with the modern facilities. This exercise helps students envision possibilities to adapted into the future M*A*S*H concept. Exercise 11c demonstrates that new technology means that the forward aid stations are much more capable and portable than in previous generations. Improved evacuation systems mean the wounded could be transported much farther and faster than previously imagined.

For the professor: Question Generation Process

Ask the students to identifying the how things could be done differently.

For the steering letter understand that the intent is really to get students to identify opportunities within the system to do it better, cheaper or faster. Part of our modernization is the network centric warfare, so discuss how internal and external users may use that data. The first step is to briefly identify what is coming into the system and leaving the system and what is generally happening along the way. Then break each of the inputs, outputs, processes, into one or two items where things can be done differently but do not mention a solution, but only identify the problems or slowdowns the antiquated processes are causing. Bring the conversation to the desired outcome at the end, so students are guided through inputs, processes, and outputs modernization. Depending on the cultural reference, allude to changing not just parts within the system, but how the entire system is used and operated.

Exercise 12a: Time, Cost, Performance Trade-offs.

Read Radar's letter home. Answer the following question in 500 to 600 words: What five implicit and explicit trade-offs are being made between cost, quality and timeliness? Comment on at least two other students' responses.

Dear Mom,

The new doctor, Major Winchester, comes to us from one of the big teaching hospitals in Boston. He prides himself on the low rate of complications his patients had back home and how he could sew up people so in a year nobody would even notice a scar. He actually came to tears yesterday after he amputated a guy's leg below the knee. At home he could have saved the entire leg with enough time and a full support staff. He called this meatball surgery. Yet he sacrificed the man's leg, and he saved two others from death. He told Hawkeye that the Hippocratic Oath said do no harm. Hawkeye reminded the major it also said do the best you can. It was hard to see such a distinguished man in tears.

Major Houlihan was in here last week demanding I call ICOR. She started screaming at the lieutenant on the other end of the phone about how dare he cut the amount of antibiotics in half. The Lt. on the other end said we were using nearly twice the surgeon general's recommendation per patient and that antibiotics are expensive. The major was screaming, and I thought she was going to reach through the phone and strangle him. I ended up trading some of the comic books to Sparky just to load up the truck with the full amount of antibiotics and change the authorized form to the full amount. I think the Lt. only monitors what is authorized and not what is actually put on the trucks.

On Sunday, Col. Potter had a long conversation with SGT. Zale. Apparently Zale is replacing tires and other parts on the trucks he is maintaining a little prematurely, and trading the used but not worn out parts on the black market for other items we need. Some of the items are not really for camp use but more for Zale's benefit. Zale is quick to point out that none of our fleet is breaking down while on the road and even flats are rare for us. What got Potter's attention was some of the items were still marked as property of the 4077th. In the future, Zale promised he will not trade anything with the 4077th on it. Potter took it as no more trading. Zale took it as nothing that was traceable. All of this business is just part of Army life.

Love, Walter

Exercise 12b: Real World Trade-offs

Describe one professional trade-off you have witnessed personally. What trade-off occurred and what could have been done differently. Justify your answer in 300 to 400 words. Comment on two other students' answers.

For the professor: Exercise 12 Methodology

Systems Engineer make decisions between getting things done quickly, cheaply or correctly. Whether it is decisions with M*A*S*H 4077th or in our professional lives, the intent is not to get into what is right or wrong, moral or immoral but to get students to understand that these trade-offs are occurring constantly in our professional and personal lives.

For the professor: Question Generation Process

Ask the students to identifying the trade space within the system.

For the steering letter understand that the intent is really to get students to identify trade space within the system to do it better, cheaper or faster. The trade space may be between hardware, software, data and people. The trade space may be between inputs, processes and outputs. The trade space may be between metrics, objectives and KSAs. Try to include examples of each of four areas to show examples.

Exercise 13a: Cost as a Constraint

Read Radar's letter home. Answer the following question in 500 to 600 words: What are the Cost As Independent Variable (CAIV) implications (Performance, functionality, schedule, staffing, and logistics) involved in Radar's letter? Comment on at least two other students' responses.

Dear Mom,

Sometimes mundane things can become the focus of the camp. The Army supplies 3 inch wide bandages in 10 and 20 foot rolls. For arm and leg injuries, that amount is plenty. However, when the injuries are to the torso, the incisions to extract the shrapnel can easily be several inches long requiring multiple rolls. The doctors have been asking for larger bandages. Leave it to our supply system to not provide anything larger. Eventually, we got rolls of bandages that were 3 feet wide and 20 feet long. These are the rolls that they cut into the 3 inch wide rolls we get. Initially, the nurses were tasked to cut the rolls into more usable sizes, but the nurses complained. Even when they did cut them up, we ended up having storage issues as the surgical trays did not have much space for the squares. We could only put a one foot wide roll in the tray, so during surgery Max and I would watch when these bandages were used and had to run and get a replacement from the supply tent. The other problem was when we got busy the nurses were too tired to cut more at the end of the day. Thus sometimes we still ran out of the larger bandages. Being medical supplies, they had to be in the supply tent or on a surgical tray only. We could not just put them on any table nearby. It was not so bad because generally the chest injuries were the first ones taken into surgery. So, once we got past the first rush, we could a little less vigilant about getting replacement rolls from supply.

*To pacify the nurses' complaints and to reduce running short during busy shifts, Captain Hawkeye made a deal with a local businessman to cut the rolls into 12 inch wide roles and twenty 12 inch squares. The businessman took three of the 3-foot rolls and gave Hawkeye 3 1-foot wide rolls and 50 foot squares. Well, as you can guess, Hawkeye was upset because the business man kept not just the 10 squares Hawkeye thought he had negotiated (1/18 of the total), but he kept the equivalent of an entire roll for himself (1/3 of the total amount). When Hawkeye confronted him, he showed Hawkeye that he had cut off 6 inches each side which potentially was 'contaminated'. Trapper then tried another local businessman who gave Trapper 5 foot wide rolls and 60 squares. He claimed to have messed up one of the long rolls and took his 10 feet allocation from the damaged roll and gave us the rest (1/9 of the total as compensation). About a week later the M*A*S*H 4060th called and asked if they could get some more 6 inch rolls, that the first guy sold them (those were the 'wasted' sections). So Trapper had the second local businessman cut some of the three foot wide rolls into 6 inch rolls in addition to the foot wide size and squares. We use some of the 6 inch wide rolls and we also traded some of the larger sized bandages to the*

4060th for other supplies. The best part was the second guy is staying just ½ mile down the road, so he comes over daily to get the number of 3 foot wide rolls he needs and cuts just enough to replace the bandages we used that day, so storage was less of a problem, and we never run out. The second guy has been more diligent than he was that first time, and as best we can tell, has been delivering just what we need in the three sizes. Yet, after two weeks, we stopped monitoring what we gave him each day, nor the amount he was actually delivering. He could be stealing just as much as the first guy, but we would not even know. Max told me he saw his wife selling some his allocation of the bandages down the road, but Max thought it was OK.

The second businessman did give Trapper some fresh vegetables for the camp as appreciation for the work. I am not sure if that was payback to compensate for some additional bandages he sold or really just appreciation.

Love, Walter

Exercise 13b: Earned Value Management (Evaluating Contract Performance)

Discuss how the doctors evaluated the performance and effectiveness of the two businessmen. What could have been done differently? Justify your answer in 300 to 400 words. Comment on two other students' answers.

Exercise 13c: Performance Evaluation (Contract Monitoring Mechanisms)

The 4077th's arrangement would be a cost plus contract in today's world. For every roll cut, 1/18 was kept by the provider. How could the Army monitor the performance of the agreement (contract), to ensure the Army was getting its value and not being cheated? Justify your answer in 300 to 400 words. Comment on two other students' answers.

Exercise 13d: Indirect Benefits and Considerations (Other Considerations)

Considering Radar's letter home, what indirect considerations or implications including advantages and disadvantages are involved in the story? Justify your answer in 300 to 400 words. Comment on two other students' answers.

For the professor: Exercise 13 Methodology

CAIV is a cost as an independent variable or cost as an independent constraint to balance against performance, functionality and schedule. In this case, bandage attrition was the cost. The functionality provided is the alternative sized bandages. The schedule was the ability to arrange for resupply as needed for surgery. The performance was the timely resupply that did not impinge upon the limited time the nurses had available to cut the bandages to the correct size. The constraints of space both on each surgical tray and in the store room were addressed by having the orderlies resupply the surgical trays as needed and the businessman making daily visits to cut the bandages on an as needed basis.

An indirect benefit is that the Army needed to only track one item (the large 3 foot wide rolls, instead of three items and shipping fewer larger items versus multiple smaller items make it simpler and cheaper. This case addresses the performance as amount of material returned in the desired sizes and the perceived honesty of the businessman doing the work. The implicit question is how to track performance and perceived integrity of the vendors compared to meeting surgical needs for various sized bandages (the primary objective). The trading of supplies for fresh vegetables was mentioned elsewhere, and the vegetable for bandages could have been appropriate transaction or the fresh vegetables could have been true appreciation for the business. We do not know if this was an ethical transaction or seen as a bribe. The ambiguity encourages the students to recognize that contractual disputes are not always black and white.

Earned Value Management is the monitoring performance for payment purposes. DOD needs to balance contract performance without creating the burden of tracking both the outgoing rolls and incoming bandages (performance metrics), which the M*A*S*H 4077th did by trusting the businessman. Initially the doctors closely monitored what went out and came in, and, as trust grew, the oversight was reduced. What if Hawkeye had tried again with the first businessman instead of Trapper switching to another provider after only one try? A simpler way for the M*A*S*H unit to monitor performance would be to track the number of 3 foot rolls ordered against the number of patients. With higher number of patients, the amount being ordered should be adjusted accordingly. A provision for the trading of the 6 inch bandages to the other units should be considered when monitoring this metric. The fact that Max Klinger monitored how much bandage material was being sold by the businessman's family was another mechanism to determine if fraud was occurring.

Although the initial need was alternatively sized bandages, the indirect considerations include the warehouse and surgical tray storage space, acquisition and shipping costs, and labor implications for the nurses and orderlies. Reducing the labor demand on the nurses and the timely cutting of the bandages are indirect labor considerations. Implicitly the additional bandage sizes might eventually result in changing of the surgical tray design to reduce the burden on the orderlies. This is an example of a change in one part of a system, necessitating changes elsewhere in the system.

For the professor: Question Generation Process

Ask the students to identifying the how decision making and trade space role into Cost As Independent Variable and Earned Value Management.

This exercise was trying to integrated decision making and trade space into an exercise to get at CAIV and EVM in particular. Although these two concepts are not generally covered in depth during the introduction courses this exercise is included as almost a capstone of the system engineering process. This exercises is intended to get students to recognize and identify trade space within the system to do it 1) better, cheaper or faster, 2) hardware, software, people and data, 3) Inputs, process and outputs, 4) metrics, goals and KSA and 5) performance, function and schedule.

For the steering letter identify a conflict in the cultural reference that is about competing priorities of the stakeholders (ignore personality conflicts). The conflicts come down to money, resources and constraints the people are working within. Try to identify a situation where three or four (ideally all five) trade spaces can be captured in a short description of the problem, where a process or system is created to satisfy the multiple competing priorities. Break the conflict into the quality, speed and cost paradigm. Identify some software, people, hardware or data implications within the conflict and mention those when describing the problem and solution. Recognize the inputs and output implications of the process and identify how it fits or skirts the metrics, goals and objective of the organization. Within cultural references, costs and finances are rarely recognized as constraints, so we shift to a functional performance vice absolute dollars in the natural conflicts. This exercise is not trying to fill in the gaps in the picture, architecture, or system design, but to recognize the multitude of tradeoffs that occur during systems engineering.

APPENDIX B. LEGO© CONCEPT: DESIGNING AND BUILDING A LEGO VEHICLE

Benjamin Franklin - “Tell *me* and I forget, *teach me* and I may remember, involve *me* and I learn.”

Using the above concept, the class readings are the tell me, the professor lecturing and associated test are the teach me, these LEGO’s Mindstorm ® (Lego) exercises are the involve me component. Here we are trying a different sort of involvement with physical mechanical set of Legos©, with the equally important discussion questions tied to each exercise. While the student is having fun doing something new and different, the discussions questions are intended to get the students recognize the implicit Systems engineering learning points involved through the Lego© game. Without the associated discussions, the Lego© exercises become just adult puzzle time which are unlikely to contribute to the analytical skill development associated with Systems engineering.

Students will learn more from the interaction with their fellow students through the discussion board (involve me), than they will from the professor, or the physical hands-on exercises of building and programming the simple robots. These exercises (and associated discussions) do cover the breadth of the Systems engineering curriculum, however the serial processing through the exercises are designed as a two semester lab experience separate from the current nine course core curriculum. As a separate lab experience, these exercises will not create a sense of continuity across the NPS systems engineering curriculum.

These system enhancement exercises may be better described as “Lego Mission Creep,” as each exercise builds on the previous exercise. To ensure that no student is left behind, a set of build instructions and software will be distributed to each student after each exercise, so the students can be corralled at the same way station (baseline) for each subsequent exercise. Mission or requirements creep may not be bad thing since that is the real world where initial requirements appear never to be truly finalized. SE 4003 Software Logic is going to be critical and that class will need to be moved to the first or

second semester (do not want to overload the first quarter intro to Lego's© exercises of building the basic robot).

The Lego's© curriculum will have one series of physical exercises and one series of corresponding discussions exercises (first 14 steps). The challenge related physical exercises (starting at 15 through 19) has unrelated discussions that can be switched up (15-20) in any order. Understanding that some students will be very mechanically inclined (building robots and alternative designs) and some will be good programmers (software logic and solutions), these exercises need to enable each student to thrive in the areas of strength, but ensure other students are not left out. The exercises provide time for students to do the assignment on their own, followed by sending out full instructions on how to build a default product and sample software that will work for the exercise class as we intend to build on the previous exercises robot (re-base lining the students). At the end they should be able to follow instructions and run the exercises for themselves without real independent critical thinking, but we want them to try each exercise for themselves first. (Extra credits for sending in video prior to distribution of software and new designs). By sending out the solutions regularly, this will hopefully prevent excessive frustration associated with small discrepancies that can disrupt the learning process. Even as the exercises build on previous efforts, the exercises are intended to include two simple things the student will need to do (adjust the physical design to handle the unbalanced three forward sensors, and adjust an intentional software bug color of start and stop colors on printed layout) even with the default information provided. These exercises are not just trying to regurgitate the systems engineering processes, but to engage the students in problem solving, and by through these unspecified curves in the student's way, will encourage continuous analytical skills in everything they are doing.

Every student will need to upload a video of the completing physical exercises with a picture of their CAC badge to identify which student did it. The staff could number the printed sheets (sent out at different intervals during the exercises), so the student and number should match and make subtle changes in the design to ensure each student is doing it. The subtle design variants may have a 10 inch run in one printed layout, and another student gets a 12 inch run, and if they do not do present the correct

layout the faculty can tell who is collaborating (lack of video). Also ensure software logic works on whichever design they are sent.

In the following exercises, there are currently 4 default designs and 14 software solutions that will need to be distributed electronically.

There will be at least two 4’x4’ sheet mailouts during the process. The faculty could put it on PDF and email it out but the paper seams creates potential problems. It may be cheaper to transmit the 4’x4’ sheets to the student’s local kinko’s and have them print it for us for printing and pickup near the students, but Kinkos does not have the simple printing online for this size printout. (Someone will need to go talk to a store manager to implement).

For this to work, the NPS lab will need to find a software package to prepare the default Lego© designs for building the solution.

Concurrently with building the physical robot of exercises 1–14, the students will be asked to address the discussion questions with a 200-400 word answer, and comment on two other student’s submission. Then the follow-up question will be posed where the students will again be asked to prepare a 200–300 word answer and comment on two other student’s submissions. These questions are intended to tie what the physical robot exercise with the systems engineering learning points.

Physical Exercises:

1. Build a simple vehicle or car that can be control to navigate a simple course. The robot and course are anticipated to be driven using a simple laptop exercise and connection cable. The default 4’x4’ single sheet of paper with the graph on it (initial default design sent here).
2. Programming the car to follow navigate a course without human interaction. This is intended to use the Lego© Block programming tool to just move the car along a path as if the human was walking the robot across the course, but preprogrammed. Simple block move forward 10 rotations, turn 90 degrees, 4 rotations, turn 90 degrees 10 rotations, sound music of victory. (1st software sent).
3. Add the camera sensor (detecting black/white line to follow). Programming the car to follow the line on the chart through the same obstacle course. Using block, check if line is present, if true move forward 1 rotation, if false turn 90 degrees, if line present move forward one rotation if not turn 180 degrees. This simple program will drive the robot right off the chart. (2nd software sent)
4. Add check to see if end spot is found, end program gracefully. (3rd software sent)
5. Add touch sensor instead of camera and run the exercise 2 software with you go until you engage the sensor. Have students place the blocking item (soda can, book etc.) in path and see if you can detect using the sensor. Sound note that blocking item encountered. (4th software sent)
6. Replace touch sensor with ultrasonic for distance, and run 5 again to stop within ¼ inch of target without touching. Reprogram and stop within 1 inch of target. (5th software sent, students tweak code for 1 inch or ¼ inch)
7. Place the camera and touch sensor on robot and let either the touch sensor of the camera stop the vehicle move forward, check sensor 1 for condition, check sensor 2 for condition. (6th software sent)
8. Place the sonar for third item for stopping (camera is downward facing, sonar forward, touch if sonar fails. This action will require robot redesign since design cannot support all three (tip over front wise). This action will require students to figure alternative design (2nd default physical design sent here, 7th software sent).
9. Create logic to go to split and take right-most course at each turn. Reverse course if block encountered and go to previous split and turn right again. Repeat process until across the 4’x4’ obstacle course. You can ask students to block 3 paths (at any point) and see if robot will make it across the course. Also include return to start check. (2nd operating area sent here with different obstacle course including different color stop circles). (8th software sent)
10. Hostile Takeover Bank has sued you over your use of the universal pivot wheel, what do you change do to change the design and avoid the patent infraction? Design and test an alternative. (3rd default design sent here)
11. The enemy has developed a mechanism to jam your sonar, so it stops working. How do you change your design and logic to compensate? Design and test an alternative. (4th default design sent here, 9th software sent).

12. Instead of running on the sheet of paper, what if you are running on your shag carpet. How do you change your design to compensate? Design and test an alternative.
13. Instead of running on the sheet of paper, what if you are running on your blanketed bed. How do you change your design to compensate? Design and test an alternative.
14. New technology integration exercise. You can use the blue tooth dongle that comes with the kit, versus the cable? Experiment? For those of you with the smart phone, load the blue tooth app and try to manually navigate the robot across the map with the blue tooth application. (Blue tooth for iphone© app sent)
15. Challenge (alternative challenges are in challenge section below) to find mines (create a model grid and navigate the model and beep of the number of targets (red marks found). Run the grid, each time beeping one additional time (display number of bombs found). So on the 8^{th} red spot, you hear 8 beeps and 8 is displayed. (10^{th} software solution sent)
16. Rerun 15, but upon finding bomb, back up, navigate around it (on safe side) and resume search pattern. (Did they check for bombs on the navigate around?) (11^{th} software solution sent)
17. Design a mechanism to pick up obstacle/bomb (toy block 2”x2”) deposit in safe area (each block individually or all). (5^{th} default design sent, 12^{th} software solution sent)
18. Rerun 15, but to pick up obstacle during search pattern. (13^{th} software solution sent)
19. Program the robot to get across the 4’x4’ chart without touching or moving bombs, crossing no black lines (navigate around) and get across. Logic problem, software, did it work? (14^{th} software solution sent)

Discussion Exercises:

1. What are the components of the car system? What are the component requirements? Breaking a system into component parts, engine, motors, battery, software, design, users, builders, maintainers, road builders.
   a. Why the car, objective of the exercise (navigation), but could a horse, tank, boat, plane, or train be used as alternative?
2. Who are the stakeholders in a car system? What are their interests?
   a. What are their relevant performance metrics each stakeholder cares about?
3. What are the requirements of the car?
   a. Test procedures for the car to ensure it is meeting the requirements?
4. Your Lego© exercise is to test the camera sensor to follow the line across a sheet of paper. How would you test that the camera is working? Test procedures, and how do you determine the operating parameters of the sensor (how much light is needed, at what distance, at what shading of line (light blue, dark blue, shades of gray).
   a. What was your experience in finding the red dot, did it stop on the orange one, the yellow one, the black dot? Practical experience of running physical exercise 4 above. Testing the sensor independently in part 1, how to test sensor within the system?
5. Your Lego© exercise is to test the touch sensor to terminate a movement as you cross a sheet of paper. How would you test that the touch sensor is working? Test procedures,

and how do you determine the operating parameters of the sensor (how much light is needed, at what distance, at what shading of line (light blue, dark blue, shades of gray).

    a. What was your experience in finding the red dot, did it stop on the orange one, the yellow one, the black dot? Practical experience of running physical exercise 5 above. Testing the sensor independently in part 1, how to test sensor within the system?

6. Your Lego© exercise is to test the ultrasonic sensor to terminate a movement as you cross a sheet of paper. How would you test that the ultrasonic sensor is working? Test procedures, and how do you determine the operating parameters of the sensor (how much light is needed, how does it work with metal, wood, fabric, cardboard and at what distance, angle of encounter (direct-perpendicular, angled -45 degree, oblique-rounded object either pencil, medicine bottle, soda can).
    a. What was your experience in finding the red dot, did it stop on the orange one, the yellow one, the black dot? Practical experience of running physical exercise 5 above. Testing the sensor independently in part 1, how to test sensor within the system?
7. You are building a minesweeping robot (previously referred to as a car) to detect physical mines and buried mines (colored dots). What are the mission requirements that your robot is required to meet. (CDD creation)
    a. New technology, what other sensors would you want, need or design to meet the mine clearing technique.
8. For your minesweeper, what performance metrics should be and how do you measure them?
    a. Think of a minesweeper stakeholders, what are their metrics and how do you measure them?
9. If you had been using the default design provided, how did you place all three sensors on the robotic car?
    a. What can you do to improve the design (not tipping over, not getting in the way of other sensors, what compromises made? (Putting two touch sensors on either side of sonar?)
10. You have been directed to change the car/minesweeper design, how did you do it and how well did it work, and what tradeoffs did you accept?
    a. Reviewing your solution and that of your classmates, which do you like best and why? (Racking and staking alternatives)
11. You have been directed to change concept of operations to remove the ultrasonic sensor, how did you do it and how well did it work, and what tradeoffs did you accept?
    a. Reviewing your solution and that of your classmates, which do you like best and why? (Racking and staking alternatives). Does touching the bomb matter versus ultrasonic detection?
12. You have been directed to change operating environment, how did you do it and how well did it work, and what tradeoffs did you accept?
    a. Reviewing your solution and that of your classmates, which do you like best and why? (Racking and staking alternatives)

13. You have been directed to change operating environment, how did you do it and how well did it work, and what tradeoffs did you accept?
    a. Reviewing your solution and that of your classmates, which do you like best and why? (Racking and staking alternatives)
14. When looking at your latest design, what are the single points of failure, and how would you remediate those critical systems? (risk mitigation and reliability block diagrams)
    a. If you added pieces to improve stability it added weight, cost and maintainer repair time when it breaks? What are the implications of your changes? (trade-offs)
15. When running the mine finding challenges operation above, you beep and count the number of targets found. What other data could you record, transmit and process? (location of bomb, type (physical or buried), when, total found.)
    a. What metrics would you think is useful for our minesweeper effort? (cost, assembly time, % of bombs found, determine mine detection probability?)
16. How else can you use this minesweeper, what other missions would it be useful for?
    a. How else could you do this mission? You assumed the car is the only way? (Israelis pioneered explosive lines to clear path through mine fields, Flier pioneered using sensors to identify mines from air, remote detonation techniques)
17. You have been asked to be able to pick up the block, what other thinks could you do to achieve the mission?
    a. How would your programming logic change if you had two units to clear the same area? Split it in half, share data of where bombs are, transmitting locations, improving probability of bomb detection?
18. Who are the stakeholders in a minesweeping system? What are their interests?
    a. What are their relevant performance metrics each stakeholder cares about?
19. You have been asked to find mines, mark mines, clear mines and get across mine field all on the same robot. What would be your goal (all in one or multiple systems?)
    a. What are the strengths and weaknesses of the model, robot, minesweeper.
20. How will you measure the maintainability of the car, the reliability of the car, the usability of the car? Define metrics and measurements and discuss how they relate to the car. How do you quantify the performance improvement you made to the car?
    a. How do you evaluate the effectiveness/suitability of the above changes?

Alternative Lego© challenges

- Challenge 1: Follow route and find and remove blocking object (mine clearing) Variance 2, remove multiple objects and deposit object in safe zone
- Challenge 2: Follow route and when encounter block, go back and follow alternate path (so the route will have 3 splits, only one path get through. (remember last block and go back, known choices locations as marked). Block can be red spot/line or physical object.
- Challenge 3: Follow search pattern and place item on red market on preprinted pattern, (marking a mine in the field)
- Challenge 4: Find marker, then find red spot to place marker on. Run pattern looking for both, can find either order, should remember red spot if see it or just search for blocker, then search for red spot.
- Challenge 4: Based on orienteering scoring event (or like a scavenger hunt), you want to get the most points in the shortest time, and picking up or going to ten spots in order will maximize points, but if robot moves 2 inches per second, cannot get to all spots in order in 1 minute, spots are distributed in a manner that the total distance between items is more than 120 inches. Using linear programming to determine optimal path to maximize points. If you get the 10th item first, you get 1 point, 9th item you get 2 points, if you get the 1st item last you get only 1 point (12-(order of item pick up + item number)) (or something similar).
- Challenge 5: Can you program both robot minesweepers to work together, what is the logic, how would you implement it?
- Challenge 6: Send out default software with color coding of stop go dot reversed, and let students find the bug and fix it themselves?

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APPENDIX C. THE SIMULATION

The following is the outline of the logic of a distance learning simulation or game that the students can use to reinforce the systems engineering learning points.

Once the students have gone through the exercise, the intention was to have the students do the M*A*S*H 4077th simulation. The students would play the part of "Sparky" who fulfilled all the logistics requirements for the unit. Radar puts together the requests, but someone is on the other side. Every item ordered serves its direct purpose, but fluctuations in the demand separate from patient related demand, should alert sharp logisticians (and systems engineers) of problems within the system. The students will be asked to provide the needed items to the camp. The simplest model is a static patient load, and fixed pricing where demand is relatively fixed only fluctuating by units per shipping container size. The model can be incrementally more complicated depending on the level as desired. The costs of the items, patients and the failures/problems can be incrementally added to the mix to save money and minimize the costs to the Army. The final step is to randomize the entire process so that no two games are alike, and so each player will experience a different number of problems to recognize. The game can have a help screen, or just let the students drop in and experience the entire thing themselves.

Initially, the teacher can implement a simple type of error, which will start in a specified week, and until the student implements the associated request, the extra supplies will be requested each week.

Below are descriptions of the types of failures that the logistician should be aware of and their impact on the model.

The M*A*S*H 4077th has been achieving a high level of life savings, but its logistics footprint is well above that projected by the Army's Surgeon General Command. The way to identify inefficiencies is to look at the material usage, when you see that the x-ray paper is twice that projected, by asking Radar O'Rielly, you can identify that they are not using only the middle three of five film frames because the mounting role is damaged. There will be no request to fix the x-ray machine, you need to

ask. When you look at the personnel allocation reports, you see they need four nurses running oxygen canisters during surgery, because the distribution switches are broken, and each patient needs their own canister, making inefficient usage of staff and oxygen canisters. (The personnel allocation reports are not part of the current simulation). When you look to their fuel usage, you see they are running on a more inefficient backup generator because they cannot get spare parts for the primary generator. You look at their paper consumption; you have to ask the clerk that he is trading toilet paper for fresh vegetables because the vegetables coming out of Seoul are spoiling en route. When you look at the penicillin usage, you will find they are trading surplus with the French for antiseptics for cleaning that is not getting to the M*A*S*H. The sterilizer is slow in heating and is taking longer, but this will only be seen in a nurse clocking extra hours every other night. It will look like a pattern, but if the patients come in uniformly, the staffing levels should be uniform. If any one looks at the food level, you will see they are feeding 150 on the Surgeon General dime, when only 100 are on the roles, because they are feeding people rolling through the area. Not a bad thing, but the unit should be billing the Amy Food Services for the extra expenses. Ask the right question of the right person and you can get surprising results, such as the technician replacing fluids nightly versus after 10 tests, where the daily average is five. This is a training issue, but you need to see the test performed and associate that with material used. This is similar to the x-ray film, but the problem is training compared to material. Also look at what material is listed on the unfulfilled requisition lists. If they have need for a cauterizing tool, they have to use extra bandages to compensate. So for the sake of a $40 part, we are using an extra $40 of supplies to compensate. Inversely, they have requested a $2,000 specialized intravenous feeding system to save the labor intensive task of measuring out appropriate portions. The cost is high compared to the non-emergency room labor requirements. It will make the nurses job easier, but is not going to save money or allow the reduction of people as in it is a NICE to have versus requirement.

There is what they request, what you requisition (approve to be sent to the unit), what gets shipped by Seoul (from the warehouse), what is being received at the M*A*S*H unit. You can approve a requisition, but it may not get shipped and even if

shipped it does not always arrive (theft, damage, spoilage, etc.) as requested. Need to watch all three, because you cannot control what is actually shipped, or arrives. Trucks do get destroyed while trying to deliver supplies to the unit. (Current the simulation does not include a lost on the way feature).

You have parts/material usage, labor and requisition reports to review, but until you review them compared to the Surgeon General's (SG) estimates, you will not find out where your problems are. We can have the extra penicillin buried in the reports, so that you should see any anomalies. In ship-based reliability, availability and maintainability (and cost), I can look at automated data collection systems to performance identify items that are less efficient, taking more power than anticipated, or operating at higher than projected vibration, temperature, fluidity levels to identify problems. Here we are doing a manual process. Looking at the unusual part requests, can you see the extra wheels and engine that Walter "Radar" O'Reily is shipping home one part at a time? (Joke, but in the most advanced scenarios developed…)

Unfortunately, we are asking SME to review shipboard system performance data, or just look at trends trying to identify problems, and when reviewing a set of problems, we try to identify the offending parts, system that needs to be replaced, but it is not yet well automated and I cannot image how to do this for the general systems engineering students.

Lego© Simulation Variations:

We can have a fixed number of patients through the system each day, or vary the number of patients. We can have even flow of 10, mild fluctuations of 5–15 per day, or go wild and have from 0 to 40 per day. We can look at supplies on a per customer basis. The X-ray film, penicillin, bandages, should be directly related to patient throughput.

For an extreme case, if the Mobile M*A*S*H unit has to move, there are many onetime items that will be needed. Concrete floors help prevent infections, so the doctors want concrete floors whenever possible. They poured concrete in one episode, so you can see ordering three tons of concrete to poor a floor. Until that is done, they will require

double the antiseptics, and 50 percent increase in penicillin than without the concrete to offset the possibility of the infections. This is a onetime cost per move.

Water is always an issue, so a drill a shallow well (cost) and they can purify the water with the water filtration system. Otherwise, they have to take stream water, which will require additional water treatment chemicals. Finally, the stagnant water of a pond will be needed and require triple the clean water chemical supplies. Also while the well sourced water will result in a highly reliable system (0 percent chance of failure), the stream water will have an increased water system failure (5 percent per week), or pond water with a 25 percent chance of water plant failure. So the impetus for a well is pretty significant. The pump/well drilling/piping is a one-time cost per move. If the water treatment plant fails, you will need 100 individual water treatment kits (enough purifying tablets for 1 per for 1 week). The camp staff can drill the well, but balancing the chemical usage, the crew will ask for technical assistance, which will reduce chemical usage. Chemical water treatment usage is related to patient numbers, and with more patients, you get additional demand, and additional chemical usage. Above the patient count of 30 patients a day, the water usage is less efficient and chemical usage will jump, and not be a linear relationship. This jump will result a staff demand signal for a SME to assist. After visit, training will result in a linear chemical usage the same as the fuel usage below.

Electricity has a main generator, which is efficient, but requires regular maintenance parts (generator spare parts) which will appear monthly. If the parts do not come within two weeks, the generator will shut down. And the backup generator will be used. The fuel usage doubles with the backup and the backup has backup parts requirements that will need to arrive within a month, and the camp orders additional parts after two weeks, while continuing to order parts for the main generator. The fuel usage is the primary difference between the primary and backup generators. Spare parts for both (spark plugs, belts and lubricants are what are in the spare parts kits) are ordered every four weeks for the primary, two weeks for the backup. Backup parts come in two weeks later, so they never really shut down. However, if they are not shipped as expected in the

first week, you will get orders for other items, so Radar/Klinger can swap the other items for the needed items as needed.

In our model, fuel is one kind for vehicles and power at the plant. Fuel consumption for power and vehicles is pretty constant and balanced between the two, whether patients come in or not. A more complex model will have fuel consumption increased proportionately to account for patients, but for each patient results in a 1 percent change. So If I get 15 patients a day in basic model, if I get 40 patients, I get a 25 percent increase in fuel, but when the patient load drops to 0, we save about 15 percent of the fuel. Figure 50 percent power is based on generator size, so if we switch to backup power, we move to 125 percent fuel consumption. Fuel delivery (absence of fuel) is assumed as needed, and we never run out. Klinger will swap fuel back and forth at no cost with adjacent units.

The basic funding model is that there is no cost, and the student is trying to identify ways to just get through the process. Ideally, you just send them everything they want and then try to identify why items are outside the projected usage rates. The second phase is that the team/students have a budget and have to prioritize items for sending to the M*A*S*H 4077th. The third model is that they have colors of money, operating (food and supplies), medical (penicillin, antiseptics, and bandages), operating contractors (to fix x-ray machine, generators), and capital equipment (pumps, generators, refrigerators, water filtration systems). The issue with model three, you will see that the by spending capital money you can save operating money, but capital money is not always available.

The above includes sending out a technician, which can provide staff training and repair capabilities but this is expensive, and sometimes the crew will request help and sometimes they will not. The three SME help items will be the x-ray machine to fix the equipment, the laboratory technician to train staff to reduce chemical costs and the final help will be for the water filtration system.

Trading between units is common even today. When items are not provided, the barter system kicks in and items requests that are coming in will jump to compensate. So for no obvious reason, additional items that have nothing to do with patient demand will

be seen. The government officially bans this barter system for logistics tracking service but the model will become obvious at the higher levels. Any time the camp has to trade something, figure that the items sent to the allies will be worth between 150 percent and 200 percent of the value of the items needed. Sometimes, it is better to trade away penicillin at a cost of $200 for the generator spare parts that cost $100, than to have the electricity powered by the back-up generator using twice the fuel than to wait for the parts to arrive. This will not always be the case of a net savings. If I am trading bandages and food for penicillin, or fresh vegetables, this could obviously be disadvantageous to the team.

Food is a basic necessity for the troops and the M*A*S*H unit; however, there are fresh vegetables/juice/fruit and dry goods. The food is tracked in both fresh and dry units per person. For example, the unit need 150 dry units of food per day, (for a camp with 100 staff members, and 10 patients per day). If fresh vegetables are spoiling, the loss of fresh will result in a 50 percent increase in dry good usage. A refrigerator (iced or actually cooled) truck can be used for the delivery and storage; however it comes with a cost, and that results in an increase food costs of 10 percent, 20 percent or 40 percent. If it the increased cost is only 10 percent, the choice is actually obvious go for the additional cost. If the cost is 20 percent, on cool weeks, you will see food spoilage will be minimal and no change in dry goods needed. If the cost of fresh vegetables is 40 percent higher, it will become cost effective for the staff to forgo the fresh foods entirely, and just plan on trading for supplies locally. Most advanced version (future model version) will allow surplus space on the medicine truck for fresh vegetables (upon request), but that can be minimal depending of penicillin and blood demand. This multi-tasking incurs a 5 percent cost for the items that are shipped via the medical trucks. The 5 percent cost unit saves the 50 percent increase in dry goods, so anything that can be shipped by the medical trucks is a savings in warm weather. In cool weather there is no loss of goods. The random generator will indicate if fresh foods are lost entirely, or percentages (0, .25, .5, .75, 1.0).

Sewage is a subject that has no immediate failure cost. Like water usage, you will have a sewage treatment process. If it fails, you dump raw sewage downstream of the

camp. There is no real cost to the camp in the basic model if sewage treatment equipment breaks down. However, after four weeks in the advanced, model, the demand for antiseptics will increase, as will penicillin. These increase in consumables will be only 10 percent based on patient demand and is lost in the details, unless the high volume patient days. This 10 percent can be adjusted significantly, but is a subtle cause and impact relationship. We could also change the four weeks to following week, but future model influence. Political impacts of dumping sewage are outside the scope of this model. If we never fix the sewage situation, we could add some supplies delivered to the local population (antiseptics and food just gone and additional orders required).

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APPENDIX D. ADDITIONAL EXERCISE TOPICS

The following are a discussion and list of additional exercise topics that were deemed secondary or too narrowly focused for the broader PD-21 or SE 311 curriculum. Creating additional exercises and phase 2 questions could lead to M*A*S*H overload on the students, and dilution of the primary learning objectives. If the professors focus too much on their narrow specialized areas, there is a chance of the key learning points never being covered in any of the course's exercises.

- A contributing factor to failures are frequently social (user involvement) not technical. A frequent problem is we let the architecture drive the system, and not let technology, processes and people drive a solution. The system may be truly extraordinary, but if the systems cannot be maintain, personnel trained to operate and/or maintenance it, or it involves a cultural shift, the failure may be preordained. Additional contributing factors to deployment and integration failures are space constraints, part and tool availability, or accessibility within current support structure, all may result in the resultant system not being suitable. Data validation and feedback loops are critical for modern systems to ensure the system is meeting the requirements and data flow is part of that verification process. Historically, data processing for patient treatment was separate from logistics support, and separate from program management (process evaluation). However, the data processing can be monitored as part of a condition based management process, and the same data can be leverage for multiple uses, and it should be. By doing multiple questions within exercise 4 on the same data management, students may begin to understand how to leverage data for other uses. However, focusing further on data uses risks becoming too narrowly focused for inclusion.
- Many of our digital systems today use internal digital sensors to monitor itself and its performance (referred to as bit level testing) but can also share that data if so designated. This bit level test data can provide systems engineer with a plethora of data to monitor logistics, system performance, usage profiles, operational effectiveness and many other purposes. However, this level of data analysis which

can be overwhelming for the operator and maintainer is deemed so component level that being able to extract, evaluate and filter the data effectively would be an exercise in component level management and although part of the system's engineer potential tool set, was deemed too specialized for inclusion in these exercises.

- Although two of the exercises specifically address programmatic concerns, there is a whole range of management related discussions that the systems engineer will need to address throughout their careers. These include requirements and metric identification and trade space both within the performance categories and stakeholder needs. These valid questions were evaluated and excluded from the exercises as being too narrowly focused and not relevant to a traditional physical lab experience and this online laboratory exercises.

Additional M*A*S*H exercises

Here are some specific phase 2 exercises that were intentionally dropped from the M*A*S*H exercises and where they could be integrated back in.

1d) How high of an objective should be set, and what is an acceptable cost escalation to meet that objective requirement (above the threshold requirement)?

> *The objective is to have the students try to do a cost benefit analysis between a 90% versus a 95% objective and whether the additional cost is justified.*

1e) How do these metrics support the mission effectiveness?

> *The objective is to have the students try to tie specific metrics back to the top level objectives and the larger holistic picture.*

1f) What tradeoff among stakeholders and their requirements can be made?

> *The objective is to have the students recognize they can never satisfy all stakeholders, and they will need to prioritize among competing priorities.*

2d) What is the cost effectiveness of meeting each requirement to accommodate a specific stakeholder?

The objective is to have the students recognize the cost implications of meeting specific stakeholder needs and to differentiate between need and wants.

3e) What is the cost effectiveness of adding the redundancy as a risk mitigation technique and is the implication of not adding the redundancy?

The objective is to have the students recognize the tradeoffs between reliability, cost and supportability or cost, performance and timeliness.

4f) Digital Data overload is a concern for maintainers, logisticians and operators. How would you limit or prioritize the data being shown to the operator, user, or repairer?

The objective is to have the students prioritize what data is needed to effectively monitor and tell the story of the systems effectiveness and performance.

7c) How would you staff a program office to ensure that each of the functional areas were managed and the area interface issues were properly addressed?

The objective is understand you can manage any program by staffing, equipment, consumables, durables, training, logistics in a number of different management structures.

9c or 11d) How would you transition the Army from the M*A*S*H process to the new alternative medical support system?

The objective is to understand not just the current state and future desired state, but to articulate the processes needed to transition between the two.

11e) What is the logistics infrastructure changes that would be required using the commercial concepts and what logistics support philosophy should be used for a M*A*S*H unit?

The objective is to have the students recognize changing the system will require changing the logistics support concepts as well. This leads to performance based logistics discussions, which are important to the system engineer but not central to the curriculum.

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